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TABLE OF CONTENTS—VOLUME XXXVII

CONTENTS OF No. 1

PAGE

HUFFAKER, CARL B.—The Temperature Relations of the Immature Stages of the Malarial Mosquito, *Anopheles quadrimaculatus* Say, with a Comparison of the Developmental Power of Constant and Variable Temperatures in Insect Metabolism 1

CARTWRIGHT, O. L.—New Scarabaeidae from United States (Coleoptera) 28

BOESEL, M. W., AND SNYDER, E. G.—Observations on the Early Stages and Life History of the Grass Punky, *Atrichopogon levis* (Coquillett) (Diptera: Heleidae) 37

ISELY, F. B.—Correlation Between Mandibular Morphology and Food Specificity in Grasshoppers 47

DELONG, DWIGHT M.—A New Species of *Plummerella* (Homoptera, Cicadellidae) from Mexico 68

DEBACH, PAUL—Environmental Contamination by an Insect Parasite and the Effect on Host Selection 70

KNULL, J. N.—Notes on *Agrilus* with Descriptions of Two New Species (Buprestidae: Coleoptera) 75

ROTH, LOUIS M., AND YOUNG, FRANK N.—*Culex* (*melanoconion*) *atratus* Theobald in Florida; A New Continental North American Record, with Notes on the Other Melanoconions of the South-Eastern United States 84

WEBER, NEAL A.—The Neotropical Coccid-tending Ants of the Genus *Acropyga* Roger 89

KNULL, DOROTHY J.—Nomenclatorial Notes on Cicadellidae 123

Proceedings of the Thirty-eighth Annual Meeting of the Entomological Society of America 124

Book Notices 69, 83, 88, 123

CONTENTS OF No. 2

MADDEN, A. H.—The External Morphology of the Adult Tobacco Hornworm (Lepidoptera, Sphingidae) 145

FROST, S. W., AND HABER, V. R.—A Case of Parental Care in the Heteroptera .. 161

KRAMER, SOL—The External Morphology of the Oblong-Winged Katydid, *Amblycorypha oblongifolia* (DeGeer) (Orthoptera, Tettigoniidae) 167

ZIMMERMAN, ELWOOD C.—Douttia, a New Genus of New Hebridean Curculionidae (Coleoptera: Cryptorhynchinae) 193

REMINGTON, CHARLES L.—The Relationship of *Dasymutilla permista* Mickel to *Dasymutilla quadriguttata* (Say) and Behavior Notes on the Species 198

RAU, PHIL—Anthropomorphism in Insect Psychology 201

BROWN, JOHN H.—The Fleas (Siphonaptera) of Alberta, with a list of the Known Vectors of Sylvatic Plague 207

MAYER, ELMER L., AND BABERS, FRANK H.—Head-Capsule Measurements of Southern Armyworm Larvae (*Prodenia eridania* (Cramer) 214

SMITH, CARROLL N.—Biology of *Ixodes muris* Bishopp and Smith (Ixodidae) .. 221

ROTH, LOUIS M.—Studies on *Tribolium confusum* Duval. III. Abnormalities Produced in *Tribolium confusum* Duval by Exposure to Acetic and Hydrochloric Acids 235

BROWN, F. MARTIN—Notes on Ecuadorian Butterflies. IV. The Genus *Penrosada*, New (Lepidoptera, Satyridae) 255

471527

TABLE OF CONTENTS—[*Continued*]

PAGE

HUCKETT, H. C.—A Revision of the North American Species Belonging to the Genus *Hydrophoria* Robineau-Desvoidy (Diptera: Anthomyiidae).... 261

ALEXANDER, CHARLES P.—New Species of Crane-Flies From South America. Part XI. (Tipulidae, Diptera)..... 298

Book Notices.....160, 192, 200, 206, 220, 297, 322-324

List of Members, Entomological Society of America..... v

CONTENTS OF No. 3

SMITH, CARROLL N.—The Life History of the Tick *Ornithodoros coriaceus* Koch (Argasidae)..... 325

MICHENER, CHARLES D.—A Comparative Study of the Appendages of the Eighth and Ninth Abdominal Segments of Insects..... 336

REINHARD, H. J.—New North American Tachinidae Belonging to the Genus Muscopteryx (Diptera)..... 352

SOMMERMAN, KATHRYN M.—Bionomics of *Amapsocus amabilis* (Walsh), (Corrodentia, Psocidae)..... 359

FLANDERS, STANLEY E.—Observations on *Comperiella bifasciata*, an Endoparasite of Diaspine Coccids..... 365

KENNEDY, CLARENCE HAMILTON—The Female of *Aeshna rufipennis* (Odonata: Aeshnidae)..... 372

DORSEY, C. K.—Mosquito Survey Activities at Camp Peary, Virginia..... 376

Book Notices.....351, 358, 364, 371, 375, 387

CONTENTS OF No. 4

DOS SANTOS, N. DIAS—Description of the Male of *Erythrodiplax maculosa* (Hagen) (Odonata: Libellulidae)..... 389

BORROR, DONALD J.—Additional Notes of *Erythrodiplax maculosa* (Hagen) (Odonata: Libellulidae)..... 393

MUNSON, SAM C., AND YEAGER, J. FRANKLIN—Fat Inclusions in Blood Cells of the Southern Armyworm, *Prodenia eridania* (Cram.)..... 396

SMITH, FALCONER—Nutritional Requirements of Camponotus Ants..... 401

LAWSON, CHESTER A.—The Relation of Hind Tibiae and Sensoria to Intermediacy in Parthenogenetic Aphids..... 409

MCGOVRAN, E. R., YEAGER, J. FRANKLIN, MAYER, E. L., AND MUNSON, SAM C.—Effect of Potassium Fluoride and Pyrethrum on *Periplaneta americana* (L.) after Hemocytes Are Blocked with Chinese Ink or Nephrocytes are Stained with Trypan Blue..... 414

BUGBEE, ROBERT E.—Eleven New Species of Eurytoma from Mexico (Eurytomidae: Hymen.). Parts III and IV. Breviura and Aureata Groups..... 420

RAU, PHIL—The Nesting Habits of the Wasp, *Chlorion*(*ammobia*) *pennsylvanicum* L..... 439

SLIFER, ELEANOR H.—Ileal Caeca in the Eumastacidae (Orthoptera)..... 441

GREGG, ROBERT E.—The Ants of the Chicago Region..... 447

Book Notices.....392, 408, 413, 419, 440

Corrections (Errors and Omissions)..... 481

Index to Volume XXXVII..... 483

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THE TEMPERATURE RELATIONS OF THE IMMATURE STAGES OF THE MALARIAL MOSQUITO, ANOPHELES QUADRIMACULATUS SAY, WITH A COMPARISON OF THE DEVELOPMENTAL POWER OF CONSTANT AND VARIABLE TEMPERATURES IN INSECT METABOLISM[1, 2]

CARL B. HUFFAKER,
University of Delaware,
Newark, Delaware

INTRODUCTION

For half a century medical men, biologists, engineers, and many other anti-malarial workers have increasingly endeavored to bring the world's most devastating disease, malaria, under control. Its widespread prevalence in the southeastern United States is attributed largely to the activities of the mosquito vector, *Anopheles quadrimaculatus* Say, which serves as the definitive host of the *Plasmodium* parasites which are the causative agents of the malady. A principal method in the control of the disease throughout the world has been the prevention of breeding of anopheline mosquitoes. Although the literature on these forms has grown very rapidly, few attempts have been made to determine their reactions to isolated and controlled environmental conditions. Field investigations have been very numerous, but these have been under such a complexity of circumstances that only a very fragmentary knowledge has been obtained concerning the specific factors and combinations of factors that contribute to their success in nature. It has

[1]This paper is a revision of a dissertation presented to the Faculty of the Graduate School of The Ohio State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy. It is a joint contribution from the Department of Zoology and Entomology of the Ohio State University and the Department of Entomology of the University of Delaware, the work at Delaware being carried on under a Purnell project entitled "Mosquito Investigations."

[2]The author wishes to express his appreciation to Dr. Z. P. Metcalf for his encouragement in the early pursuit of the general problem; to Drs. D. M. DeLong, F. L. Campbell, and Harold E. Waters for valuable advice during the major part of the investigation; to Dr. Paul L. Rice, and Harvey L. Chada for suggestions concerning the manuscript; and to Fenton T. West for making some of the observations.

471527

been generally recognized in recent years that it is essential to make a thorough, basic study of the ecology of the species concerned before the greatest mosquito control achievements can be accomplished.

This paper is the result of an investigation into one of the foremost physical factors in the limitation of *Anopheles* throughout the world. This factor is temperature. For the first time, a comprehensive description of the developmental reactions of *A. quadrimaculatus* to temperature is presented.

The relation of temperature to various aspects of the ecology of poikilothermic animals in general probably has received more attention than any other feature of the environment. As Chapman (1931) stated, "It probably affects animals more evidently and in more ways than any other factor." Réaumur (1736) recognized that there is a quantitative relationship between the activities of organisms and temperature, and first suggested the thermal constant concept. In his excellent discussion of the relation of climate to insects, Uvarov (1931) stated that over 1300 papers were reviewed by him, and that this figure is only representative, for hardly a paper has been published in economic entomology without some data concerning temperature. Merriam's work (1894) is an example of the contribution of temperature studies to human endeavor. His major conclusions, based upon temperature summation data, even though unsound in many cases, unquestionably gave tremendous impetus to the study of the factors governing the geographical distribution of organisms and to biological and agricultural advancements in general. Bělehrádek (1935) published what is perhaps the most recent extensive paper on the temperature relations of living matter. Bachmetjew (1901, 1907), Davenport (1908), and Kanitz (1915) also have contributed important earlier papers.

In spite of the considerable attention that has been given to the temperature ecology of insects, much remains to be learned, and many concepts need to be placed on a more generally acceptable, firm basis. Three considerations of primary importance are taken up in this work: 1. The temperature relations in the development of a thermally unspecialized insect, *A. quadrimaculatus*, are followed independently for all the developmental stages, and differences and similarities between stages are established. 2. The relative developmental powers of constant and variable temperatures are viewed in the light of the catenary formula, concepts advanced by Blackman (1905) in the field of botany, and previous and present experimentation on the subject. 3. An attempt is made to further the acceptance of the catenary formula of Janisch (1925) as an adequate expression of the time-temperature relationship of insect development.

Any attempt to evaluate the metabolic power of variable and constant temperatures must be based upon a great number of experiments. Only after the relation of the constant throughout all limits of survival has been worked out can a suitable comparison be made. In order to attach to this comparison a basic ecological or physiological significance, it is necessary to use a species, or developmental stage, that does not represent a high degree of specialization to the temperature factor. If development involves a special demand upon the temperature environ-

ment, such as the breaking of diapause, this development cannot be considered critical in generalized comparisons of the variable and the constant.

It is for this reason that a representative of the tropical and subtropical genus *Anopheles* Meigen was chosen in the present effort. The additional fact that the development of this species, *A. quadrimaculatus*, occurs in a medium of water adds to its utility in such a study. In nature, the changes in the water temperatures where this form abounds are much slower than are air temperatures. During much of the summer, at the height of the breeding season, the day and night water temperatures certainly do not vary to the extent of the laboratory variations imposed upon this species in the present investigation. Therefore, any differences in development that are found cannot be attributed as readily to the normal adaptation of the species, as might be the case with most terrestrial, temperate climate insects.

CONCEPTS ON THE RELATION OF TEMPERATURE TO DEVELOPMENT

Even today there is no general acceptance of a mathematical means of expressing the developmental reaction of poikilothermic organisms to temperature changes. It is necessary, therefore, to re-examine the relation of constant temperature to the metabolism of these forms. Since, from simple physics and chemistry, it is known that temperature greatly affects chemical and physical phenomena, it is not surprising to find it playing an important part in the life of organisms. The mechanists have maintained that all biological processes have explanations that are fundamentally assignable to the laws of chemistry and physics. Regardless of the truth of such a view, it is certain that many such processes do have their explanations in physical and chemical laws. Solation, gelation, coagulation, surface tension, diffusion, imbibition and viscosity are a few of the more basic physical phenomena that are greatly affected by temperature. All chemical reactions are subject to changes with temperature. When it is remembered that temperature may affect each process to a somewhat different degree and that changes of varying degree and kind may take place in an organism at the same or at different times, then it is not alarming that it has been impossible to fully explain the effects of temperature in ecology or physiology. It is, rather, most astounding that such direct correlations and effects are observable!

Early Formulae.—As early as 1862, according to Bělehrádek (1935), Berthelot first used a formula for the rate of some chemical reactions in relation to temperature, from which the Q_{10} rule may be derived. However, van't Hoff (1884) proposed a new equation which is the mathematical formula of the statement that for each temperature rise of 10° C., the velocity of most chemical processes increases two to three times. This formula may be expressed as

$$\frac{K_t + 10}{K_t} = Q_{10} = 2 \text{ to } 3$$

However, he showed that this Q_{10} may vary from as low as 1.20 to as high as 7.14. Therefore, biologists are in error in applying the expression "van't Hoff's law" to biological phenomena. The effect of increased temperature is thus expressed as a multiplication of a known rate at a lower temperature.

Argo (1939) pointed out that, even though the temperature/respiration curves of Krogh and the temperature/velocity-of-development curves of Krogh, Shelford, Janisch and others conform to the reciprocal of the catenary of Janisch, temperature/respiration studies on adult insects have failed to support such catenary curves and instead do support simple exponential curves of the van't Hoff or Arrhenius type.

The "law of Arrhenius" is derived from the "van't Hoff Law." Arrhenius (1889) used the constant μ to bring Q_{10} closer to 2. In chemical reactions this constant (the thermal increment of Crozier) varies from 4,000 to 35,000, according to Crozier (1924). This latter author utilized the thermal increment to explain the underlying reaction governing complex biological processes. However, his work has found little approval. The explanation of complex biological processes, involving many limiting physical factors as well as chemical ones, invariably in terms of simple oxidative reactions, and necessitating the view that the reaction curves have sharp changes in velocity at "critical points," cannot be accepted at present. The formula of Arrhenius may be expressed as

$$K_1 = K_0 e^{\frac{\mu}{2}\left(\frac{T_1 - T_0}{T_1 T_0}\right)}$$

where K_1 and K_0 are velocities at the absolute temperatures T_1 and T_0 respectively, μ is the constant, and e is the base of natural logarithms.

The rule of thermal summation, suggested by Réaumur (1736) and given quantitative expression by Boussingault in 1851 (according to Bělehrádek, 1930), is the most familiar rule of temperature reaction of insects. The works of Hennings (1907), Peairs (1914), Krogh (1914), Blunck (1924), Bodine (1925) and others are well known examples of the application of this rule. It is, simply, that the temperature, expressed in effective degrees, multiplied by the time required is a constant. For medial temperatures this rule is a good practical method of expressing the relation of temperature to insect development. According to this rule, the velocity of reaction is a straight line when plotted against temperature. Prochnow (1907, 1908), Krogh (1914), Shelford (1927), and many later authors have now firmly established that there are significant departures from the straight line at both ends of the biokinetic scale. Shelford (1929) accepts this expression as conforming to the observed facts only for about one-third of the range of temperatures (medial temperatures) compatible with life.

The formulae so far mentioned fall into the following two categories:

1. Exponential formulae based on the velocity of chemical reactions of various types (van't Hoff's rule, Arrhenius' formula, and Janisch's catenary formula or "exponential law").

2. Those where the velocity is expressed as a linear function of temperature (Réaumur, Krogh, Peairs, Bělehrádek, Wardle and others).

The Catenary Formula.—Since it has been repeatedly shown that the value of a degree is not developmentally equivalent everywhere in the biokinetic scale, it is obvious that the straight-line relationship formulae have no basis either empirically or theoretically. As a result, they fail entirely as a means of describing the reaction curve at the extremes of temperature.

The catenary curve of Janisch (1925, 1932) is the mathematical formula that seems most adequate as an expression of the relation of temperature to the development of insects. Janisch's formula is derived directly from the "exponential law" of that author (1925). This "law" is based on the law of mass action and hence, "The fact that the influence of temperature in chemical processes can be expressed by an exponential curve—i. e., that the velocity constant is an exponential function of the temperature—is a law on a theoretical basis and not merely an empirical rule." Though both μ and Q_{10} have proved inadequate as expressions of the relation of temperature to biological processes, a catenary curve has been shown to be a good expression of this relation by Cook (1927), Menusan (1934) and Janisch (1932). The present effort is further proof of the utility of the curve. The reciprocal of this catenary curve, plotting velocity of reaction against temperature, has the characteristic S-shaped form of the biological curve. It is almost identical to the thermal unit curves of Shelford (1929). The formula of this catenary curve is

$$t = \frac{m}{2}(a^{T} + a^{-T}),$$

where t = time, m = developmental time at the empirically determined optimum, a is an empirically established constant which determines the slope of the curve, and T is the temperature in degrees above or below the optimum.

This curve is derived by the addition of two simple exponential curves. Janisch (1925) states, ". . . this means biologically that two things working opposingly are added, a positive function, the acceleration of developmental processes through rising temperature, and a negative function, the retardation and injury in the processes of development." Below the optimum the accelerative effect is largely determinative and above the optimum the opposite is the case. It is seen, therefore, that certain factors which retard development are not suddenly operative just as the optimal temperature is passed, but are present as contributing elements even at very low temperatures. These factors assume an ever-increasing role in the velocity of the reaction as the temperature is increased, gradually assuming the dominant function. Above the optimum, the accelerating factors are still operative, but now decrease in importance in conditioning the observed velocity.

The writer has never held with the generally accepted view that death at high temperatures is associated with coagulation of protoplasm. This theory also is in opposition to such a view. Observations on the general symptoms of approaching death at high temperatures, for *A. quadrimaculatus*, suggest that with proper techniques it might be possible to show that death at high temperatures is related to starvation at lower temperatures. It seems possible that, at barely lethal high

temperatures, nutritive substances are oxidized so rapidly that the supply cannot keep pace and no net increase in mass or necessary developmental change can occur. Digestion, diffusion, transportation in the blood stream, or the removal of waste products of metabolism may be partly limiting.

Regarding this catenary formula, Harries (1939) stated, "Although the equation has the advantage of being applicable to data through a wide range of temperature, the descriptive advantage in flexibility obtained through the use of numerous constants gives an indefinite character for the shape of the regression curves." However, it remains a fact, admitted by Harries, that this formula is the only one yet advanced which is generally applicable to the complete reaction data. It is appropriate also to question the criticism that the formula lends an indefinite or plastic character to the reaction velocity curve. Plasticity is an inherent necessity of any formula applicable to both the rising and descending arms of the multitudinous variety of developmental curves. Such a formula must be conformable to the fact that organisms themselves possess the character of endless variability in response. The slope of the velocity curve shall therefore be dependent upon where in the temperature scale the optimum and the "threshold" (or an equivalent concept) lie for the particular species or stage. It is necessary, therefore, that a parameter dependent upon the optimum and one dependent upon the "threshold" (or else upon the slope of the curve) be included in the formula. Essentially all formulae used in such studies have some feature which utilizes the concept of the "threshold" or other empirically determined value. Since they do not encompass the post-optimal arm of the velocity curve, they do not possess features concerning the optimum.

The constants in the catenary formula, a and m, are, therefore, necessarily determined from the empirically established data. Sufficient points must be established in the vicinity of the optimum to establish the optimal temperature and the developmental time at that temperature, and also at some point in the medial temperature section of the velocity curve so as to establish the developmental time at a given temperature in that vicinity. If the reaction is adequately determined at two such positions, the remainder of the reaction curve can be generally predicted by the resultant catenary curve and/or its reciprocal.

In the present work, the constant for slope, a, was determined by averaging the velocities at all medial constant temperatures, converting to the corresponding time value, and solving for a of the catenary formula. Due to the small number of points established in a given series in the vicinity of the optimum, m had to be established largely by visual interpolation between points.

Variable and Constant Temperatures.—For many years it has been known that variable and constant temperatures produce different rates of insect metabolism. Chapman (1931) and Imms (1937) have reviewed the literature on this subject. These authors state that the data were not conclusive as to whether exposure to variable temperatures results in a rate of development, or general metabolism, greater than does exposure to the numerically equivalent constant temperatures.

The probable general explanation of the reason for an increased rate of metabolism under variable temperatures, compared with constant, was discussed by Blackman (1905), several years before the subject received attention in entomology. As a result of his botanical studies on the carbon assimilation of cherry laurel under different temperatures, he stated the following conclusions:

1. At high temperatures (30° C. and above for the leaves of cherry laurel) the initial rate of assimilation cannot be maintained, but falls off regularly.
2. The higher the temperature the more rapid the falling off.
3. The falling off at any given temperature is fastest at first and subsequently becomes less rapid.

Bayliss (1913) looked upon these conclusions as a complete explanation of the effects of temperature upon enzyme reactions. Cook (1927) and Kanitz (1915) reviewed this work of Blackman, and the latter author disagreed with the conclusions. Cook's work on the effect of variable temperatures on the metabolism of *Porosagrotis orthogonia* Morr. seems to be in agreement with the principal thesis. The results of the present investigation also will be shown to be in conformity.

Statements by Peairs (1914, 1927), Janisch (1925, 1932), Cook (1927), Shelford (1927, 1929), and Parker (1930), reveal that insect development under variable temperatures is faster than that under constant. Peairs found that development was as much as 12 per cent faster under the variable, for blowfly larvae, if the temperature was changed each six hours. The average acceleration, however, was about 7 per cent under several conditions of alternated temperatures. Shelford (1929) stated that the pupal stage of the codling moth, *Carpocapsa pomonella* L., is about 7 per cent shorter under variable temperatures. Cook (1927) found a 37 per cent increase over the constant for *P. orthogonia*, and Parker (1930) increases of 70 and 80 per cent for the development of the eggs of the grasshoppers, *Melanoplus mexicanus* Saussure and *Camnula pellucida* Scudder. Parker also revealed that the total food consumed in completing growth by the nymphs of *M. mexicanus mexicanus* (Saussure) was only two-thirds as great under variable temperatures as under constant. Cook further showed that the metabolic rate, as exhibited by CO_2 output, is faster under variable temperatures. Shibata (1934) found that the percentage of sexual and parthenogenetic females and also the sex ratio of *Callipterus kurikola* Mats. was greatly affected by rearing under different conditions of alternating temperatures.

On the other hand, Ludwig (1928), as a result of work on the developmental rate of the Japanese beetle, *Popillia japonica* Newman, reached the conclusion that only if the high temperature is between the threshold and the optimum and the low temperature is below the threshold does an acceleration under the variable occur. Headlee (1914, 1929, 1940, 1941) also has presented conclusions in repudiation of the claim of a fundamental increase in the metabolic power of the variable as compared to the constant. He (1914) found a slightly higher rate of reproduction of the grain aphis under variable temperatures, up to 20° C. Above this temperature, however, he found the constant to be much more powerful. The use of temperatures above the optimum, in

variable units having a mean above 20° C., probably accounts for the lower metabolic power of the variable above that average value. His results (1940) showed constant temperatures to be far more powerful than variable on the development of codling moth pupae, *C. **pomonella*** L. and also for the development of the yellow fever mosquito, ***Aedes aegypti*** L. In the first case the results are contradictory to the work of Shelford previously cited. Both 90 and 100° F. (the high temperatures used) are post-optimal for the mosquito and the results, therefore, do not refute the claim of an acceleration of development under variable temperatures.

Headlee (1941) published data very different from his earlier work on the same mosquito. In this case he found a decided increase in the velocity of development under the variable condition, where the temperature varied daily from 50 to 80° F. This series is of the greatest value in the present consideration, for both the maxmium and the minimum were clearly between the threshold and the optimum. Headlee omitted this series from discussion and purported to show that the acceleration of the 60 to 90° F. variable lot is explained on the basis of the ". . . speed of accumulating the thermal constant." In so explaining, he apparently made an error in his calculations. Furthermore, it seems perfectly obvious to the writer, having studied his apparatus as well as his data, that his variable and constant temperature lots accumulated thermal units at exactly the same rate. In listing his summary in degrees he utilized 31 temperatures, but in determining the exposure per day for each temperature, he used only 30. And again, he utilized 14 temperatures but determined the daily exposure for each on the basis of 13. In each case the error involved is sufficient to completely nullify the conclusions from the calculations. He further stated that, ". . . the underlying and governing factor of such differences as exist in the variable and constant temperatures is the accumulation of the required amount of temperature, regardless of whether the temperatures in question come from constant or variable sources." This statement appears to be unfounded, even from consideration of his data alone. The works of many other authors and the results herein presented are certainly not compatible with this viewpoint.

METHODS

During all the work herein reported, 25 eggs or newly-hatched larvae of *A. **quadrimaculatus*** were used in each experimental lot of insects. A total of six experiments, following the development from stage to stage, were conducted for the larval and pupal stages. Each experiment involved approximately eight lots exposed to constant temperature and from ten to fifteen lots exposed to alternating high and low temperatures; a total of 130 lots and 3250 larvae. Except when otherwise stated, the figure used to indicate a developmental velocity is based upon the average time required for the first half to transform. There is every reason to believe that for this species, under these conditions, such data are more critical with respect to the temperature factor than are data based upon the average time required for all to transform, since the latter half transforming are more apt to be subject to a limiting food factor than the first half.

In these experiments, two temperature-controlled water-bath cabinets were used, one in the Department of Zoology and Entomology of the Ohio State University and the other in the Department of Entomology of the University of Delaware. Temperatures were accurate to ±.5° C. for each compartment. Readings were taken twice daily with a U. S. Bureau of Standards thermometer, graduated to one-tenth degree Centigrade. It was possible, therefore, by averaging these readings, to get results that were probably accurate to ±.1° C. for a total period of development.

The variable temperature lots were moved by hand at stipulated times. The mosquitoes were reared in containers having celluloid walls and bandage cloth bottoms. The culture water, therefore, was not moved and the insects very quickly came to the temperature of the new compartment. This probably produced some shock, but apparently not a great deal, for lots that were moved twice daily developed faster than those shifted only once daily.

The pH values varied from 6.9 to 7.5, which is generally accepted to be in the vicinity of the optimum for this species. Senior-White (1926) showed that the range of tolerance of the genus *Anopheles* to H-ion concentration is relatively large. No interference from this source was encountered.

The larvae were fed powdered dog biscuit, recommended by Crowell (1940). Hinman (1930) showed that *Anopheles* exhibits little food preference and can successfully utilize a great variety of food substances. Furthermore, microscopic observations of culture water revealed an abundance of Infusoria at all temperatures. Larvae reared in water changed daily, which never supported the larger Infusoria such as *Paramecium*, developed in nearly the same period of time as those reared in normal cultures. These protozoa apparently supplemented the dog biscuit diet, but only slightly, particularly between feeding times. Inasmuch as this was a highly extreme case, it is certain that a comparable food difference in any of the experimental lots did not exist.

REACTION OF THE IMMATURE STAGES TO CONSTANT TEMPERATURES

In Table I and figure 1 is presented a comprehensive analysis of the reaction of the immature stages of *A. quadrimaculatus* to constant temperatures. The observations on development for these experiments were made at intervals of six hours. Approximately 25 individuals were used in each experiment, and duplicate experiments were conducted at most temperatures. "Optimal temperature" is used as the temperature at which the rate of development is highest. However, it is recognized that this is a developmentally optimal temperature only, and may bear no rigid correlation with the optimal temperature for maximal expression of biotic potential, considering the total life span. Equally as limited in its use is "optimal survival temperature," which is the optimum used by Price (1940).

In figure 1, both the time required to complete the stage (plotted against temperature as the catenary curve) and the velocity of development (plotted against temperature as the reciprocal of the catenary curve) are presented for each instar. The reciprocal has the sigmoid

TABLE I

THE DEVELOPMENT OF THE IMMATURE STAGES OF THE MALARIAL MOSQUITO, *Anopheles quadrimaculatus* SAY, UNDER CONSTANT TEMPERATURES

Stage	Temperature, Time and Velocity	Observed Data									Calculated Values at Optima
Egg Stage	Temperature in °C.	10.0	14.5	18.3	22.0	25.4	28.6	31.8	34.8	.....	33.3
	Time in Hours	492	192	108	69	46	39	34	34	.....	33
	Developmental Velocity (1/Time)	.0020	.0052	.0093	.0145	.0217	.0256	.0294	.0294	.....	.0303
First Instar	Temperature in °C.	12.1	14.6	18.8	21.7	24.4	27.0	29.4	32.5	35.1	32.5
	Time in Hours	275	168	111	68	53	41	35	31	33	30
	Developmental Velocity (1/Time)	.0036	.0060	.0090	.0147	.0189	.0244	.0286	.0323	.0303	.0333
Second Instar	Temperature in °C.	.....	14.6	18.9	21.7	24.5	27.2	29.7	32.3	34.7	32.2
	Time in Hours	.....	144	96	54	35	33	30	24	29	26
	Developmental Velocity (1/Time)	.....	.0069	.0104	.0185	.0286	.0303	.0333	.0417	.0345	.0385
Third Instar	Temperature in °C.	.....	14.4	18.9	21.7	24.5	27.2	29.7	32.5	34.7	31.0
	Time in Hours	.....	156	87	47	43	36	34	32	33	30
	Developmental Velocity (1/Time)	.....	.0064	.0115	.0213	.0233	.0278	.0294	.0313	.0303	.0333
Fourth Instar	Temperature in °C.	12.1	15.7	18.9	21.9	24.5	27.0	29.5	32.2	34.3	30.0
	Time in Hours	365	180	119	96	69	62	56	56	70	55
	Developmental Velocity (1/Time)	.0027	.0056	.0084	.0104	.0145	.0161	.0179	.0179	.0143	.0182
Pupal Stage	Temperature in °C.	12.1	15.6	19.2	22.0	24.7	27.2	29.6	32.2	34.4	30.5
	Time in Hours	206	120	89	59	46	39	36	36	39	35
	Developmental Velocity (1/Time)	.0049	.0083	.0112	.0169	.0217	.0256	.0278	.0278	.0256	.0286
Eclosion to Emergence	Temperature in °C.	12.1	15.1	19.2	22.0	24.7	27.2	29.6	32.3	34.6	31.0
	Time in Hours	1572	768	501	319	245	210	190	178	203	176
	Developmental Velocity (1/Time)	.0006	.0013	.0020	.0031	.0041	.0048	.0053	.0056	.0049	.0057

form of the biological curve, and, in fact, is preferred in such studies, because it places greater emphasis upon the critical positions of the biokinetic scale, without changing the fundamental relations. The observed points are plotted only as velocities, but the developmental time at a given temperature can be read directly from the catenary curve itself. In Table I are presented the observed data and the calculated data at the optima.

The following paragraphs are devoted to the discussion of the reactions of the several stages to constant temperatures.

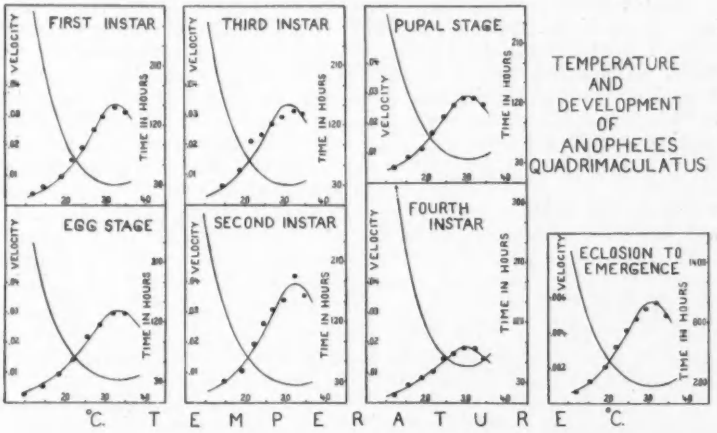

FIGURE 1. Developmental reaction of the immature stages of *Anopheles quadrimaculatus* under constant temperatures. Both the catenary, $t=(m/2)\ (a^T + a^{-T})$ and its reciprocal are plotted. In this formula, t=time, m is the time required at the optimum, a is a constant, and T is the temperature in degrees Centigrade above or below the optimum—based on average emergence. All curves are for the "Wilson Dam, Alabama Strain." The constant, a, is 1.130 for the egg stage, 1.155 for the first instar, 1.145 for the second instar, 1.155 for the third instar, 1.155 for the fourth instar, 1.145 for the pupal stage, and 1.150 for the period from eclosion to emergence. The constants, a and m, were determined in the manner described on p. 6.

Egg Stage.—The embryonic development of this mosquito has the highest optimal temperature of any stage—33.3° C. The time required at this temperature, as derived from the catenary curve, is 33 hours. The observed data for 8 temperatures are presented in Table I, and graphically in figure 1. The observed time from deposition of the eggs to hatching varied from 492 to 34 hours as the temperature varied from 10.0 to 31.8° C. It can be seen in figure 1 that the departures of the observed points from the curve are not great.

First Instar.—For the first instar the optimal temperature was 32.5° C. The hypothetical time required to complete the stage at this temperature, as derived by use of the catenary formula, is 30 hours.

The observed data for the 9 temperatures are presented in Table I and figure 1. The observed time required to complete the stage varied from 275 to 31 hours as the temperature varied from 12.1 to 32.5° C. It should also be noted that those larvae which completed the stage at 12.1° C. probably represented a small minority of very vigorous individuals, which, unlike the others, were able to utilize the small amount of thermal energy available to them and complete the necessary processes of development. The drop in the velocity of development above 32.5° C. is in accord with the hypothetical curve. The departures of the observed points from this curve are relatively small.

Second Instar.—The optimal temperature for the second instar was 32.2° C, the time required to complete the stage at this temperature, as derived from the catenary curve, being 26 hours, the shortest of any stage. Table I and figure 1 present the observed data at 8 temperatures. The observed time required for this stage also varied greatly, from 144 to 24 hours as the temperature varied from 14.6 to 32.3° C. When it is considered that the threshold of larval development for this species is about 7° C., it is safe to predict a developmental time at a temperature of 12.0° C. The hypothetical time required at this latter temperature would be 210 hours. The general form and steepness of the curve, as well as the optimal temperature, for the second instar is, therefore, notably the same as for the first. Though the departures of the observed data from the hypothetical curve are greater in this case, when it is considered that the observations were made only at intervals of 6 hours, the discrepancy is of little concern.

Third Instar.—The optimal developmental temperature for the third instar was 31.0° C. The hypothetical time required at this temperature, as taken from the catenary curve, is 30 hours. Observed data at 8 temperatures are presented in Table I and figure 1. The time required at the lowest temperature, 14.4° C., was 156 hours, while only 32 hours were required at 32.5° C. Again it is safe to predict a hypothetical developmental time of about 240 hours at a temperature of 12.0° C. The form of the velocity curve is identical with that for the first instar, but the numerical velocity values for the medial temperatures were greater, indicating that this stage was completed in somewhat less time than was the first instar.

Fourth Instar.—The optimal temperature for the fourth instar was 30.0° C. The time required at this temperature, as derived from the curve in figure 1, is 55 hours. A significant difference in the developmental curve for this stage, as compared to those of the other stages, is that the time involved is nearly double that of the other instars. This is to be expected. It is general knowledge that the fourth instar is the one in which a great portion of the body size is attained and which requires much more time in its completion. This stage, as here considered, includes the prepupal form. The same relationships of the other instars exist in this double stage. The time factor alone is different. By lengthening the developmental velocity axis in figure 1 to twice its present dimensions, while holding the temperature axis the same, a velocity curve would result that would be essentially the same as the others. The observed data at 9 temperatures are presented in Table I

and figure 1. The observed time required to complete the stage varied from 365 to 56 hours as the temperature varied from 12.1 to 29.5° C.

Pupal Stage.—The optimal temperature for the development of the pupal stage was 30.5° C., the required time, as derived by use of the catenary formula, being 35 hours. As with the fourth instar, the completion of the pupal stage requires somewhat more heat energy than do the first, second, and third instars. However, the time involved is not nearly so great as for the fourth instar. The empirical data for 9 temperatures are presented in Table I and figure 1. The observed pupal period varied from 206 hours at 12.1° C. to 36 hours at 29.6° C. There are no significant changes from the considerations as expressed for the other stages.

Eclosion to Emergence.—The four larval instars and the pupal stage are here considered together as the developmental stage, thus omitting the egg stage. The optimal temperature was 31.0° C., the time required from newly-hatched larvae to emergence of adults being 176 hours, or 7.3 days, as derived from the catenary curve. The general action of temperature upon the velocity of development of this mosquito is presented in figure 1. The observed data for 9 temperatures are presented in Table I, the time required from eclosion to emergence varying from 1572 hours, or 65.5 days, at 12.1° C. to 178 hours, or 7.4 days, at 32.3° C.

Discussion.—The position of the developmentally optimal constant temperature in successive stages in the development of an unspecialized species should have a direct bearing upon the whole problem of the relative power of variable and constant temperatures in metabolism studies. Parker (1930) showed that the optimal temperature and the general temperature relation for eggs of ***M. mexicanus mexicanus*** were far different from the relations of the nymphs. This raised the question as to whether temperature studies should be confined to a single stage.

If the optimum temperature changes from one instar to another, it should change in some consistent manner. If the value of a high constant temperature is at a maximum only at the beginning of exposure and falls off with time, it would be expected that the earlier instars of a lot of insects which were held at a given pre-optimal high temperature throughout their entire development would have a higher optimum than the later instars. This is because they would have derived the maximum benefit from the initial exposure to the high temperature before the accumulative injurious effect of the high temperature has made itself felt to a great degree. The species of grasshopper studied by Parker is not a suitable example for such consideration. He has shown that the stimulating effect of cold temperatures on the hatching of the eggs of this species is tremendous. The egg stage occupies an entirely different ecological position in the cycle of this species from that of the nymph. Each is adapted to the respective physical conditions which normally prevail during the development of that stage. Hence, the fact that the optimal temperature for the eggs was much lower than for the nymphs, in this case, does not obscure the aforementioned fundamental deduction.

The data for the development of the four larval instars and the pupal stage of this mosquito taken as a unit, when compared to the

data for the component stages, offer no reason whatever to necessitate consideration of the several stages of this species separately in a study of this kind, even though there is a shift in the optimal temperature from one stage to the next. For other species of insects, as Chapman (1931) suggested, it might be necessary to confine such a study to a single stage. This example may be taken as representative of a single basic type, but the results do not preclude data to the contrary concerning species whose ontogenetic form relationships are fundamentally different.

The several graphs of figure 1, presenting the developmental curves of the egg stage, the first, second, third, and fourth instars, and the pupal stage, may be used to test these several considerations. From an examination of these curves and Table I it can be seen that the differences in the time-temperature developmental relationships from one stage to another are largely of the quantitative order rather than the qualitative. There is a decided drop in the optimal temperature as development progresses from the embryonic to the pre-imaginal phases. This difference is from about 33.3° C. for embryonic development to about 30.3° C. for the fourth-instar and pupal stages—a difference of 3.0° C. (5.4° F.). The shift is largely consistent, always proceeding in the same direction.

The following are two possible explanations of this phenomenon:

1. The decrease in the optimal temperature is correlated with the same factors which contribute to the developmental accelerations resulting from variable temperatures as opposed to constant. As greater and greater time is spent at a given high temperature the developmental efficiency of that temperature is more and more reduced. That is, the initial rates of the metabolic processes are not maintained. This alternative assumes that there is no fundamental difference in the true optimum of one stage as compared with another, providing all previous development has been spent at the same low temperature. This explanation is supported by the fact that development was somewhat faster for those lots of larvae that, under variable temperatures, experienced a shift in temperature every six hours as opposed to those that experienced shifts every twelve hours (see Table IV). The rate of accumulation of thermal units (hour-degrees) was the same in each case. It is further supported by the fact that on several occasions individuals which had undergone their total larval development at about 35.0° to 35.5° C. died in the pupal stage at that temperature, whereas individuals that had been reared at 25.0° C. until pupation completed the pupal stage at the high temperature of 35.0 to 35.5° C. This exhibits the accumulative injurious action of high temperature.

2. There is also some deductive reasoning which suggests that there may also be a difference in the true optimum of different stages. As the developing form grows in size and becomes more complex in its metabolic demands, the problem of supplying the tissues with the necessary constituents for anabolic processes and of the removal of waste products of metabolism becomes increasingly more acute. Though the mechanisms concerned are enormously changed and made more efficient, it is possible that they do not completely keep pace with the added burden of supplying a rapidly increasing volume of living tissue,

and of continually readjusting the balance of a vigorous metabolism. Hence, the relative balance between anabolic and katobolic processes is changed so that the originally optimal temperature no longer supports the greatest net product of growth and development. No experimental results were obtained to support this view.

The writer is of the opinion, however, that both the aforementioned explanations are operative and that neither is correct to the complete exclusion of the other.

The several stages vary considerably in the actual time required in completion. Obviously, a stage that requires a much greater total growth as well as basic tissue transformation (such as the fourth instar) will require a longer time for its completion if the same basic rate of growth and development, in terms of unit mass of material added or transformed, is maintained. Without establishing the quantity of such changes within each stage, it is impossible to compare the true rates of growth and development of the different stages. Nevertheless, it is of considerable interest to see if the same fundamental type of curve applies to the rates of development for all stages. In this case and in all the work herein reported, the rate of development is not a true rate, but is based on the portion of the total development of a given stage (not quantitatively comparable to that of another stage) that is completed in one hour. The scale used in plotting the rate of development is, therefore, of no importance. As previously stated, by changing the scale it can be shown that the same fundamental velocity curve applies to all stages. However, the velocities are plotted on the same scale, so as to show that the total quantity of changes taking place at one stage may require decidedly greater amounts of time than that at another. It is seen that those stages which undergo the greatest and most profound growth and transformations are the ones that require the longest time. These are the egg stage, fourth instar, and pupal stages. The fourth instar, involving by far the greatest increase in mass as well as marked qualitative changes, required approximately twice the time of the first, second, and third instars. It also required much more time than either the egg or pupal stages.

Crowell (1940) stated that, under optimal temperature, a total of about 23 days are required for the larval and pupal development of this species. The present data have established that as short a period as 7.3 days may be sufficient to complete this development. Crowell was writing from experience with rearing larvae under laboratory conditions at a temperature of about 24° C. (75° F.). He reared 300–500 larvae in a 20″ x 12″ flat, enameled rearing pan, and there is no question but that food was the limiting factor rather than temperature. Also, considering 24° C. as optimum was a mistake so far as developmental velocity is concerned. However, that probably is a good culture room temperature, considering the longevity of adult life, mating, total oviposition per female, vigor, mortality during development, etc. The time required at 24° C. in these experiments was 12 days rather than 23. His results were with a Florida stock which had been in captivity several years, whereas these data are largely from a Wilson Dam, Alabama, stock which had been in captivity only a short while. It is felt that this is also a partial explanation of the greatly different figures.

Viewing these data, it is obvious that under the most favorable conditions in nature the entire larval and pupal gamut could be completed in one week, and ordinarily would require from one to three weeks, depending upon the temperature and nutrition factors as the most commonly prevailing limiting conditions. In determining the interim between larvicidal applications, it is obvious that the speed with which the species develops under the particular conditions should be considered. Temperature is of primary importance where food is abundant, but it is probable that the limiting factor will vary somewhat from one breeding condition to another—even from one very small microhabitat to another within a general breeding area.

Another way in which these data may be utilized in practical work is that it should now be much easier to determine the temperature at which purely physiological and medical experiments with this insect should be conducted.

THE THRESHOLD, "OPTIMAL SURVIVAL," AND HIGH AND LOW LETHAL TEMPERATURES

The threshold of development of *Anopheles quadrimaculatus* has not been accurately determined. Criteria of development at such low temperatures are not very dependable. The threshold is certainly below the highest low-temperature death point (11° C.). Definite development was observed at 8.5° C., but this was not measurable, for the first stage was never completed. At this and lower temperatures the larvae spend much of the time lying inactive on the bottom. However, they can be made to come to the top and perform feeding movements. At 6° C. no observable development occurred. Hence, about 7° C. may be taken as at least an approximate threshold.

The differences in survival under variable and constant temperature conditions were found to be insignificant in these experiments when medial temperatures were employed. A comparison of survival under such conditions is presented in Table II. Average survival to maturity under constant temperature conditions was 83.3 per cent, while under two types of comparable variable temperature conditions the survival was 76.6 and 78.9 per cent, respectively. These differences may in large part be accounted for by the mechanical injury and entanglement in fungus mycelia, due to moving the larvae from one unit of the temperature cabinet to another. With regard to the constant temperature data, there seems to have been a peak of survival, 92.0 per cent, at about 29.6° C., which is also near the temperature of highest velocity of development. This may mean only that there was a shorter period of exposure to the ever-present danger of entanglement in the fungus mycelia.

For temperatures above the optimum or those definitely below the straight-line portion of the velocity curve there is a sharp reduction in survival as the temperature is increased in the former case or decreased in the latter. Constant temperatures of 10° C. were lethal to all larvae, and it is probable that 11° C. also would be, for at 12.1° only 1.7 per cent completed development and attempted emergence. Since these did not successfully emerge, even this temperature may be considered too low for the completion of development. At 15.7° C. only 20.0 per

cent developed to adults. Above the optimum, at 34.4° C., only 44.0 per cent completed development, and at 35.0° C. no emergence occurred. Considering other data not herein tabulated, a temperature of 35.0° C. permitted about 50 per cent to pupate, but these died in that stage. At a temperature of 36.1° C. all died in the fourth instar or earlier. At 38.5° C. all died early in the first instar—after 7 hours, 20 per cent were alive; after 29 hours, only 12 per cent; and after 31 hours, none was alive.

TABLE II

AVERAGE SURVIVAL OF *Anopheles quadrimaculatus* TO EMERGENCE UNDER CONSTANT TEMPERATURE AND TWO TYPES OF VARIABLE TEMPERATURE CONDITIONS*

Constant Temperature		Two 6-Hour Periods Daily at Both High and Low Temperatures		One 12-Hour Period Daily at Both High and Low Temperatures	
Temperature	Percentage Survival	Mean Temperature	Percentage Survival	Mean Temperature	Percentage Survival
10.0	0.0†	....	....	....	....
12.1	1.7†	....	....	....	....
15.7	20.0†	....	....	....	....
19.0	80.0	20.0	72.0	20.0	88.0
21.8	76.0	23.0	68.0	23.0	56.0
24.5	84.0	23.2	72.0	23.2	76.0
27.1	88.0	24.4	88.0	24.4	84.0
29.6	92.0	24.8	64.0	24.8	68.0
32.4	80.0	25.7	84.0	25.7	88.0
34.4	44.0†	27.0	88.0	27.0	92.0
35.0	0.0†	....	....	....	....
Averages	83.3	....	76.6	....	78.9

* All temperatures are in degrees Centigrade.
† Omitted from the comparative averages.

There seems to be little question that the injurious effects of high temperatures are accumulative. An occasional pupa reared previously at 25° C. was able to emerge at 35.5° C., whereas at 35.0° C., as previously stated, none emerged if reared throughout its development at that temperature. At temperatures of 36 and 37° C. even those pre-reared at 25° C. were unable to complete pupation.

COMPARISON OF CONSTANT AND VARIABLE TEMPERATURES

Both Cook (1927) and Peairs (1927) published data which show that the highest rate of acceleration in insect development under variable temperature conditions is obtained if the continuous daily exposure at the high temperature is a short period—6 to 8 hours. Cook found that the highest acceleration over that at constant temperatures was obtained by decreasing the daily exposure at the high temperature as that high temperature is increased. The data of figure 2 and Tables III and IV,

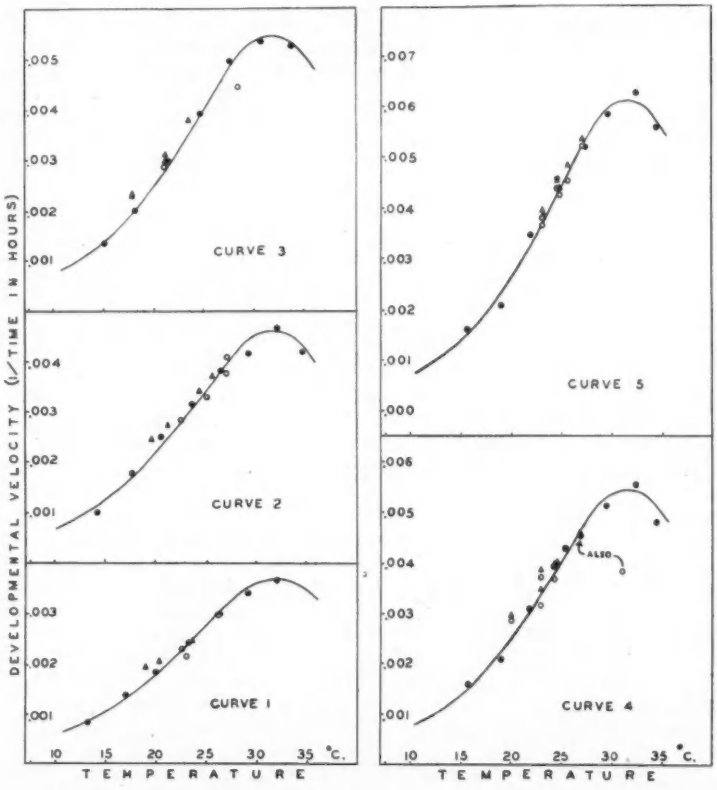

FIGURE 2. Curves showing the relation of temperature to the velocity of development, from newly-hatched larvae to adults, of *Anopheles quadrimaculatus* under constant and several types of variable temperatures. Curves are reciprocals of the catenary, $t = (m/2)\ (a^T + a^{-T})$, where t = time, m is the time required at the optimum, a is a constant, and T is the temperature in degrees Centigrade above or below the optimum—based on average first-half emergence. All curves are for the "Wilson Dam, Alabama strain" except Curve 1 which is for the "Boyd strain." Black circles represent constant temperatures. The actual curves are calculated on the basis of these constant temperature data only (black circles). Triangles represent exposures of 9 or less continuous hours daily at the high temperature, the remainder being spent at the low. White circles represent exposures of 12 or more continuous hours daily at the high temperature, the remainder being spent at the low. The complete experimental data are not numerically presented in this paper. The explanatory data for this figure follow:

Curve	Data for Establishment of Curve			Daily Exposure to High Temperatures	
	Optimal Temp.	m	a	Triangles	White Circles
1	31.8° C.	274 hrs.	1.120	One 9 hr. Period	One 15 hr. Period
2	31.5° C.	220 hrs.	1.125	One 9 hr. Period	One 15 hr. Period
3	31.3° C.	184 hrs.	1.130	One 6 hr. Period	One 18 hr. Period
4	31.4° C.	184 hrs.	1.130	Two 6 hr. Periods	One 12 hr. Period
5	31.3° C.	161 hrs.	1.140	Two 6 hr. Periods	One 12 hr. Period

TABLE III

THE RELATION OF THE VELOCITY OF DEVELOPMENT OF *Anopheles quadrimaculatus* TO THE PERIOD OF EXPOSURE AT THE HIGH TEMPERATURE AND TO THE LOW TEMPERATURE EMPLOYED IN VARIABLE TEMPERATURES EXPERIMENTS WITH COMPARISONS TO CONSTANT TEMPERATURE DATA*

Constant temperature condition (values taken from the appropriate curves for the constant).	To Compare with "A"	Temperature		20.2	23.2	24.9	27.0
		Velocity		.00239	.00335	.00401	.00493
	To Compare with "B"	Temperature		22.8	24.8	25.9	27.0
		Velocity		.00290	.00372	.00434	.00493
VARIABLE CONDITION A — Continuous periods of 6 to 9 hours daily at the high temperature—remainder at the low.	Low Temperature		Average	15.0	19.0	23.0	24.5
			Range	12.0–16.9	17.9–20.4	21.3–23.5	None
	High Temperature		Range	24.4–31.6	27.0–30.8	27.0–29.3	29.5–29.7
	Average Temperature per Hour of Exposure		Average	20.2	23.2	24.9	27.0
			Range	15.3–23.1	21.1–26.8	23.3–25.7	26.9–27.1
	Velocity			.00271	.00345	.00418	.00498
	Percent Change from Velocity at the comparable constant temperature			+13.4	+3.0 (*Average* = *+5.4*)	+4.2	+1.0
VARIABLE CONDITION B — Continuous periods of 12 to 18 hours daily at the high temperature—remainder at the low.	Low Temperature		Average	15.0	19.0	23.0	24.5
			Range	12.0–16.9	18.0–20.4	21.3–23.4	None
	High Temperature		Range	24.4–30.7	27.0–30.7	27.0–30.6	29.5–29.7
	Average Temperature per Hour of Exposure		Average	22.8	24.8	25.9	27.0
			Range	20.0–25.6	22.9–26.9	24.3–28.3	26.9–27.1
	Velocity			.00306	.00362	.00424	.00486
	Percent Change from Velocity at the comparable constant temperature			+5.5	−2.7 (*Average* = *−0.2*)	−2.3	−1.4

*All temperatures are in degrees Centigrade, and all data are for average first-half emergence and are based upon development from eclosion to emergence. Most of the values given are based upon rearings of from 5 to 10 lots of larvae (depending upon the value considered), but the data at the average temperature of 27.0° per hour of exposure are based upon only 2 lots for each condition. The initial number of larvae used in each lot was 25. There is no way for the reader to check the derivation of the temperatures and /or other values given, since the average low temperatures and average temperatures per hour of exposure are not derived by simply averaging the values showing the range. Temperatures were very accurately recorded twice daily throughout the development of each lot of larvae, and low temperature averages were calculated for each lot. These low temperature averages for all lots in a given condition were then averaged to give the average low temperature shown in the table. Arrival at the respective average temperatures per hour of exposure was a much more involved procedure. The time exposed daily (in hours) to a given high temperature for each lot was multiplied by that high temperature (in degrees). The same was done for the low temperature employed with the same lot. These two products were then added and the sum divided by 24 to give the true average temperature per hour of exposure for the development of the lot. These values for all lots under a given condition were then averaged to give the average, average temperature per hour of exposure shown in this table.

TABLE IV

A Comparison of the Metabolic Power of Two Variable Temperature Conditions Having the Same Speed of Accumulation of Thermal Units, and Comparisons with Constant Temperature Conditions*

Average Temperatures (Low and High Temperatures in Parentheses)	Developmental Velocity at the Comparable Constant Temperature†	Two 6-Hour Periods at the High and Low Temperatures		One 12-Hour Period at the High and Low Temperatures	
		Developmental Velocity	Percentage Change Relative to Velocity of the Constant	Developmental Velocity	Percentage Change Relative to Velocity of the Constant
20.0 (15.7 & 24.4)	.00250	.00295	+18.0	.00288	+15.2
22.9 (18.8 & 27.0)	.00336	.00347	+ 3.3	.00314	− 6.5
23.1‡ (15.7 & 32.5)	.00372	.00394	+ 5.9	.00380	+ 2.2
23.1‡ (15.7 & 32.5)	.00339	.00388	+14.5	.00373	+10.0
23.2 (19.1 & 27.3)	.00373	.00385	+ 3.2	.00364	− 2.4
23.3 (12.0 & 34.5)	.00350	lethal	.....	lethal	.....
Average	.....	.....	*+ 9.0*	.....	*+ 5.7*
24.3 (21.7 & 27.0)	.00381	.00398	+ 4.5	.00369	− 3.1
24.6 (21.9 & 27.3)	.00430	.00452	+ 5.1	.00439	+ 2.1
24.7‡ (18.8 & 32.4)	.00390	.00408	+ 4.6	.00394	+ 1.0
24.8‡ (19.1 & 32.5)	.00440	.00439	− 0.2	.00424	− 3.6
Average	.....	.....	*+ 3.5*	.....	*− 0.9*
25.6 (21.7 & 29.5)	.00421	.00431	+ 2.4	.00433	+ 2.9
25.7 (21.8 & 29.7)	.00470	.00483	+ 2.8	.00452	− 3.8
26.9 (24.3 & 29.5)	.00465	.00463	− 0.4	.00450	− 3.2
27.1 (24.6 & 29.7)	.00521	.00532	+ 2.1	.00521	0.0
Average	.....	.....	*+ 1.7*	.....	*− 1.0*
Averages	.....	.....	*+ 5.1*	.....	*+ 0.8*

* All temperatures are in degrees Centigrade, and all data are for average first-half emergence and are based upon development from eclosion to emergence.

† Developmental velocities for the constant temperatures are taken from the appropriate velocity curves.

‡ Value is the result of reducing the post-optimal high temperature to the developmentally equivalent pre-optimal temperature and averaging the corrected high temperature with the low temperature.

corroborate the work of these authors. Table III shows the relation between the temperature of the low exposure and the development, under variable conditions. With daily continuous exposures of 9 hours or less at the high temperature, and when the low temperature was near 15° C. there was an acceleration of 13.4 per cent, and with low temperatures of 19 and 23° C. the acceleration over the constant was 3.0 and 4.2 per cent, respectively. When the low temperature was raised to 24.5° C. there was an acceleration of only 1.0 per cent. These figures give an average of 5.4 per cent acceleration for all low temperature exposures under this condition.

On the other hand, daily continuous exposures of either 12, 15, or 18 hours at the high temperature gave some velocities that were above and some that were below the velocities at the numerically comparable constant temperatures. Considering the data of this type of temperature variation as a whole, there would seem to be neither a retardation nor an acceleration. The average change for all temperatures, as shown in Table III, was −0.2 per cent compared to the constant. This is a negligible figure. However, Table III reveals that when the low temperature was about 15° C. there was an acceleration of 5.5 per cent. When the low temperature was about 19, 23, and 24.5° C. there was a retardation of 2.7, 2.3, and 1.4 per cent respectively, compared to the constant.

The question arises as to whether these figures representing retardation are significant. They are derived from the average first-half emergence of 14 lots of 25 larvae each for both the constant and variable temperature conditions. Of the 14 pairs of lots, 10 of the variable lots showed a retardation and 4 an acceleration. The figures for acceleration were also generally less than those for retardation. It would seem, therefore, that disregarding the group exposed to 15°, there was a slight retardation under the conditions of these experiments. It is probable that there was some slight shock or disturbance accompanying the sudden shifts in temperature.

The data of Table IV confirm the aforementioned statements and are a more detailed elucidation of a part of the data of Table III.

Returning to figure 2, which is a graphic presentation of a much greater number of results than it has been possible to present in tabulated form, some explanations and discussion are appropriate. As stated in the legend to figure 2, the curves presented are plotted on the basis of the constant temperature data only. The black circles represent all the constant temperature data obtained during the course of this study. It may be noted that, on the whole, there is a very close conformity between the formulated curve and the black circles, representing the empirical data, in every case. A total of 38 such points are established, involving data obtained at temperatures representative of the entire biokinetic range for this species, and distributed fairly equally among the five major experimental lots of larvae.

It may be observed that there is some considerable difference in the reaction presented by one curve as compared to another. Two genetical aspects are perhaps partial explanations.

The "Boyd strain," presented in curve 1, would not necessarily be expected to react to temperatures in exactly the same way as the

"Wilson Dam, Alabama strain." Also, different batches of eggs, probably in each case deposited by a few individuals, may have possessed inherent differences in temperature reaction. Furthermore, it is certain that in the case of curves 1 and 2, the method of feeding had not been sufficiently perfected so as to completely eliminate the food factor as a partially limiting condition. In the case of curve 5, the development of the entire lot was unusually fast. During much of this period there was present, unfortunately, a considerable amount of free ammonia in the rearing chamber. It is possible that this condition may have stimulated a more rapid rate of development.

In spite of the apparent differences in the reactions of the several major lots of larvae, as represented by the data of curves 1 to 5, inclusive, there remains one principal fact. This fact is that those larvae exposed to high temperatures for continuous periods of 6 or 9 hours daily developed faster than those exposed for continuous periods of 12, 15 or 18 hours daily or those exposed to constant temperatures. An examination of the position of the triangles for each example will show that all are either on the respective line representing the constant temperature data or above it, and in many cases well above. A total of 25 such points are established. On the other hand, the white circles are situated both above, below, and on the respective lines representing the constant temperature data. It should also be noted that in those cases where there are paired data for the two variable temperature conditions (see curves 4 and 5), the white circles in every case except one occupy positions representing a slower rate of development than the triangles. In the case of the one exception, the two have essentially the same position. A total of 22 white circles are established. It may be concluded, therefore, that the more extensive data presented in figure 2, as compared to those presented in Tables III and IV, are in complete agreement with the tabulated results.

It is seen from the results of Table III and figure 2 that there were both retarding and accelerating effects of sizeable daily shifts in temperature. It is highly probable that under natural variations a retardation would not occur. Only when the daily exposure at the low temperature was a long period and that at the high temperature a short one did the accelerative phase completely over-balance the inhibitive in these experiments involving sudden and large changes in temperature.

These results are in agreement with the previously discussed statements of Blackman (1905), to the effect that the maximum rate of metabolism at a high temperature is maintained only at the beginning and that the rate of decrease in this rate with time is at first fast but becomes progressively slower. Under a long exposure at the low temperature, the injurious state that has resulted from exposure to the high temperature is corrected and the insect is again in a physiological condition to sustain the maximum rate of initial metabolism when returned to the high temperature. Too short an exposure to the low temperature would not allow the complete rest or correction (whatever is the true nature of the change that occurs), and the maximum rate of metabolism could not be accomplished when the insects are returned to the high temperature.

It seems possible that the processes associated with supply of assimilable substances, utilization, and disposal of waste products in the complicated developmental process are not equally affected by temperature changes. Therefore, when there are no accumulated deleterious waste products present, and when the reserve of nutritive substances and necessary conditions are at an optimum, the highest possible metabolism can take place at a given temperature. If that temperature is relatively high, for example, the processes involved in waste disposal may not occur as fast as those responsible for growth, development, and the production of those waste products. Or again, it may be the processes of supply and translocation that are unable to keep pace. In any event, the rate of development is forced to come to a balance with the total complex of processes.

The present data may be further discussed with respect to Blackman's concepts. As previously stated, there was a decided increase in the rate of development above the rate at the comparable constant temperatures only when the period of continuous exposure at the high temperature was 6 or 9 hours. In this group there was little change (1.0 per cent) relative to the constant if the low temperature of the variable was at about 24.5° C. This result is in conformity with the statement of Blackman that below 25° C. (for carbon assimilation of the leaves of cherry laurel) there is no further falling off of the initial rate of metabolism. Hence it is presumed that if, down to 25° C., a falling off occurs, there could be no correction of the accumulated deleterious condition by exposure to low temperatures of 25° C. or above. Some of the low temperatures were as low as 24° C. It is also certain that the figure of 25° C. would not apply rigidly to another species of organism or other type of metabolic process.

When the temperature of the low exposure was reduced to 23° C. or to 19° C. for the same rhythm of variation, there was an increase in velocity of 4.2 and 3.0 per cent, respectively, above that under the constant. These differences are not large, but, when compared to the retardations in velocity (see lots exposed 12, 15, or 18 hours at the high temperature, in Table III) of 2.3 and 2.7 per cent, respectively, their magnitudes seem greater. The corrective power of these medial temperatures is not very great. When the temperature of the low exposure for this group was about 15° C. there was a great increase in the velocity of development over that under the comparable constant temperature. The increase was 13.4 per cent in this case, and compares with increases that have been reported by Peairs (1927), Shelford (1929), and Headlee (1941) under certain conditions for other insects. Headlee (1941) also obtained the greatest acceleration over the constant for the development of *Aedes aegypti* L. when the low temperature was very low (10° C.).

For the variable groups that were held 12 hours or longer continuously at the high temperature there are two factors visibly affecting the sequence of the change in velocity as the low temperature is decreased. The injurious effect of shock is increased at the same time that the accelerative phase of the variable is made more functionable. Under these conditions, however, the injurious effect continued to

dominate. Only when the low temperature was about 15° C. was there an appreciable acceleration (5.5 per cent) over the velocity at the constant.

Temperatures near 15° C., therefore, have a high corrective power. The evidence indicates that there is a rather rapid increase in the corrective or stimulating power of a low temperature as that low temperature approaches 17° C. or less for this species.

The possibility that the difference in the metabolic power of a degree (depending upon where in the biokinetic scale that degree is taken) may in part account for the observed differences in the metabolic power of constant and variable temperatures, needed experimental consideration. From the procedure used by Headlee (1941), it is presumed by the writer that Headlee had this approach in mind. However, he did not state the objective in these terms at all, but rather in terms of explaining the variation of the metabolic power of the variable and the constant as being due to differences in the rate of accumulating the thermal units. (These results have been discussed in an earlier section, p. 8.)

The validity of the previously mentioned concept can now be considered. In Table IV there are data on the velocity of the constant and of two classes of variable temperature groups. Curves 4 and 5, figure 2, present these data graphically. Any group of three in the table is made up of strictly comparable results, but comparisons otherwise are not so valid. In both variable temperature groups the total exposure was for 12 hours daily at both the high and low temperatures, and the specific temperatures involved were identical. Therefore, the rate of accumulating thermal units was identical, and, more important, the thermal energy in degrees was taken from exactly the same position in the biokinetic scale. This latter statement is not true for the constant, however. Comparing these two variable groups, it is seen that of every pair but one, the group shifted twice daily had velocities distinctly above the group shifted only once daily, the average velocity difference between the two groups being about 4.3 per cent. The variation was mostly about 3 per cent, with a maximum of 10 per cent. In the one case, the group shifted twice daily developed 0.5 per cent slower than the group shifted but once.

Nearly all the velocities in the group shifted twice daily are higher, while half of those shifted only once daily are lower than the velocities at the comparable constant temperatures. In these considerations it has not been necessary to consider the actual temperatures involved. As before, the greater increases over the constant are to be found where the temperature of the low exposure is very low. The only two large positive changes for the once-shifted group had exposures to low temperatures of about 16° C. Likewise, the two larger positive changes for the twice-shifted group had exposures to low temperatures of about 16° C.

The fact that there was essentially no net change in velocity from that at the constant for the once-shifted group signifies that when the continuous exposure at the high temperature was 12 hours the inhibitive and accelerative phases of the effects of variable temperatures nearly balanced. When shifted twice daily the insects were able to sustain

two periods daily of maximal initial developmental rate instead of one. As to why there would not have been two injurious shocks daily to off-set these is not answerable to any degree of finality. However, it may be that when shifted more often the changes become less of a shock to the developing larvae, due to a greater degree of acclimatization.

These data are in agreement with the concept of Blackman that the maximal initial rate of metabolism at a given high temperature falls off with time. On the other hand, the differences in the metabolic power of two variable temperature groups, as here shown, cannot be attributed to variations in the position in the biokinetic scale of the temperatures to which they were exposed. The known variation in metabolic power of temperature, according to its source, is not the explanation of the differences in the metabolic power of the variable and the constant. The tremendous variation between the variable and the constant, reported by some authors, *e. g.* Cook (1927) and Parker (1930), would seem to have precluded such an explanation.

SUMMARY

The reciprocal of the catenary curve, $t=(m/2)\ (a^{T}+a^{-T})$, seems to be the most adequate and adaptable method yet advanced for expressing the relation of temperature to the velocity of insect development. This formula is derived from two simple exponential functions, one representing an accelerative and the other an inhibitive effect of increased temperature.

The reaction of development of the malarial mosquito, *Anopheles quadrimaculatus* Say, has the same general form for the total period of development as for any individual component stage. There is, however, a significant shift in the optimal temperature from about 33.3 to 30.3° C. as development progresses from the embryonic to the pre-imaginal phases. The time-temperature relation in the development of this species conforms remarkably well to the catenary formula. The optimal developmental temperature is at about 31° C., and the time required to complete development from newly-hatched larvae to adults may vary from as high as 1572 hours (65.5 days) at 12.1° C. to about 176 hours (7.3 days) at the optimum. The shortest time required to complete each stage is near 30 hours (this figure is about 55 hours for the fourth instar).

The threshold of development for this mosquito is about 7° C. The lowest generally lethal high temperature is about 35° C., and the highest generally lethal low temperature is about 11° C.

High temperatures have an accumulative injurious effect; a pupa, pre-reared at about 35.0° C. is very likely to die at that temperature, whereas one pre-reared at a lower temperature and then shifted to 35.0° C. may emerge. The concept that lethal high temperatures are associated with the coagulation of protoplasm seems to be untenable; death at these temperatures may be similar to starvation at lower temperatures.

The metabolic power of variable temperatures is greater, generally, than that of constant temperatures, this difference being probably attributable to an inherent inability of the insect to maintain the initial

rate of metabolism at high temperatures. The speed of accumulating thermal units or the specific source of the thermal energy, is not the explanation. The degree of acceleration of variable temperatures is greatly affected by the exact nature of the variation. Exposure to low temperatures of 17° C. or slightly lower are far more powerful in promoting an increased metabolic rate than are exposures to higher low temperatures. The basic explanation is probably that different important phases of metabolism respond to temperature changes differentially.

Information put forward in this paper should be of value in determining the interim of time between larvicidal applications in antimalaria operations. It should also now be much easier to determine the temperature at which purely physiological and medical experiments with this insect should be conducted.

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NEW SCARABAEIDAE FROM UNITED STATES
(Coleoptera)

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The type specimens of the scarab beetles described herein will be retained temporarily in the author's collection. At some future date, the holotypes and allotypes will be placed in the United States National Museum.

Ataenius linelli n. sp.

Holotype.—Length 4.3 mm., width 1.9 mm. Oblong, moderately elongate, convex, shining, piceous brown shading to dark castaneous over head and sides of thorax; underparts of thorax still lighter; legs castaneous; antennae and trophi pale. Clypeus broadly emarginate, a small denticle each side, transversely rugose anteriorly; front moderately convex, front and sides sparsely very finely punctate; punctures of vertex fewer and only slightly larger. Pronotum strongly convex, about one-third wider than long; marginal groove strong and entire, marginal setae fine and inconspicuous; surface with mixed punctures, sparse coarse punctures unevenly but generally distributed, finer in front and coarser and closer at the sides, with interspersed very fine evenly distributed punctures throughout. Elytra convex, seven-tenths longer than wide; striae deep, moderately closely crenately punctate; intervals convex, minutely punctulate. Mesosternum shagreened. Metasternum roughened anteriorly at sides, shining at middle, with minute punctures throughout, a small group of slightly larger fine punctures on each side of median groove. Abdominal sternites shining, impunctate at middle, a transverse row of three or four well separated coarse setigerous punctures outward at the sides, the setae rather long and fine, and with a group of moderately coarse punctures at extreme edges; transverse basal row of pits well defined. Middle and posterior femora smooth, shining, with a row of three or four coarse setigerous punctures at knee; posterior marginal groove well defined one half the distance from knee, and indefinitely continued over other half; posterior tibia with accessory spinule. Sex not determined.

The eleven specimens of the typical series vary in length from 3.9 to 4.6 mm., in width from 1.8 to 2.0 mm. The clypeal denticles vary from mere angulations of the narrowly reflexed margin to low triangular teeth.

Holotype from Miami, Florida, May 1919. Nine paratypes with same data; one Miami, September, 1923. Paratypes in collections of Oregon State College, U. S. National Museum, and Mark Robinson.

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[1]Technical Contribution No. 97 from the South Carolina Experiment Station, Clemson, South Carolina.

Ataenius linelli keys to *laeviventris* in Horn's monograph but is much nearer *schwarzi* (Linell) which it resembles closely in general shape, color, and other characters. However, *linelli* differs frow *schwarzi* in that the clypeal rugosity is less strongly developed, the vertex of the head is finely punctate, the coarse punctures of the thorax are less coarse and more widely distributed, and the marginal groove of the posterior femur extends half its length.

Ataenius saxatilis n. sp.

Holotype Male.—Length 4.1 mm., width 1.8 mm. Convex, piceous, strongly shining; sides of pronotum, edge of clypeus, underparts of thorax, and legs dark castaneous; trophi and antennae pale. Clypeus broadly emarginate, each side evenly rounded without trace of denticle or angulation; feebly wrinkled anteriorly, finely punctate, minutely punctate medially, vertex with a rather wide band of moderately coarse punctures separated by one or two diameters. Pronotum about one and one-half times as wide as long, without marginal setae, marginal groove fine and entire, anterior angles obtuse, posterior angles broadly rounded, highly polished surface with generally distributed sparse irregularly spaced moderately coarse punctures separated on disc by one to four or five diameters, slightly coarser and closer at sides, and with interspersed similarly distributed extremely fine, almost microscopic, punctures throughout. Elytra about one and two-thirds as long as wide, sides not quite parallel, widest slightly beyond middle; striae fine, not deep, finely crenately quite closely punctured; intervals almost flat, the polished surface with microscopic punctures; lateral margin strongly convex. Pygidium convex, smooth, polished, with a very few scattered moderate punctures and interspersed microscopic punctures. Mesosternum shagreened and with fine short decumbent hairs. Metasternum, abdomen, and legs virtually impunctate. Two terminal abdominal segments shortened, penultimate about two-thirds the length of the preceding, terminal two-thirds the length of the penultimate. Usual basal row of pits on abdominal sternites practically invisible except under high magnification. Posterior femur without marginal groove; posterior tibia without accessory spinule.

Allotype Female.—Length 4.3 mm., width 1.9 mm. Penultimate segment not shortened. Pygidium less convex and not as long. Otherwise as in male.

The 350 specimens of the typical series vary in length from 3.5 to 4.6 mm., in width from 1.6 to 2.1 mm.

Holotype and allotype taken in copulo, Bogg's Rock, Liberty, South Carolina, July 9, 1940, O. L. Cartwright. Paratypes collected in the following South Carolina localities: Bogg's Rock, Liberty, July 9 to August 19, 1940, June 18 to September 1, 1941, O. Starnes and Cartwright; Forty Acre Rock and Haile Gold Mine (both in Lancaster Co.), Lancaster, and Jefferson, July 20, 1940, Starnes; Bald Rock, 4 miles south of Caesar's Head, July 25, 1940, Cartwright; Table Rock Mt., August 6, 1940, Starnes; Beverly, August 22, 1941, Starnes; and Camp Adger, Pinnacle Mt., August 28, 1941, Starnes. Also Stone Mt.,

Georgia, August 15, 1940, P. W. Fattig (a single specimen with much closer and somewhat coarser thoracic punctuation); Flat Rock, Flat Rock Creek, 7½ miles east of Columbus, Georgia, July 6, 1941, Cartwright; and High Falls, Little River, Buck's Forest, North Carolina, July 22, 1941, Starnes and F. K. Hinnant.

Paratypes in U. S. Nat. Mus.; Field Museum of Natural History, American Museum of Natural History, Museum of Comparative Zoology, Philadelphia Academy of Science, California Academy of Science, various university and private collections.

All specimens of this highly polished, shining, jet black species were collected in the sand washed down to the edges of pockets or islands of soil and vegetation on outcroppings of bare weathered areas of granite or gneiss rock, or in the sand and soil around the lower edges or such areas of rock.

Ataenius saxatilis is closely allied to *figurator* Harold, however, it is a more robust species differing in general shape. *A. saxatilis* increases noticeably in width from head to slightly beyond the middle of the elytra, whereas *figurator* is more slender and parallel. In addition the sides of the clypeus are more widely rounded and without even a suspicion of angulation each side of the median emargination in *saxatilis*. In *figurator* the clypeus on each side of the median emargination is more sharply rounded, usually with an evident angulation, frequently with a noticeable denticle.

Eucanthus lazarus var. **alutaceus** n. var.

Holotype Male.—Length 12 mm., width 7 mm. Apparently identical with typical *lazarus* (Fab.) in every way except that the head, thorax, and elytra are alutaceous, giving the variety a dull, greasy appearance. Such lustreless specimens are quite noticeable in a series of shining *lazarus*.

Holotype collected at Lucedale, Miss., October 4, 1931, by Henry Dietrich. Five paratypes: Lucedale, Miss., April 7, 1932, H. Dietrich; Mobile Co., Ala., June 1, 1936, H. P. Loding; Grand Bay, Ala., August, 1906, H. P. Loding; and Thomasville, Georgia, April 1, 1939, April 24, 1940, P. W. Fattig.

Phyllophaga yemasseei n. sp.

Figures 8, 9

Holotype Male.—Length 11 mm., width 5 mm. Elongate oblong, subdepressed, pale brown with head darker, glabrous, moderately shining. Antennae 9-segmented, pale testaceous club subequal to stem. Clypeus rounded with scarcely noticeable shallow emargination, concave with widely and deeply reflexed margin, surface mod-

EXPLANATION OF PLATE

Aedeagi. Fig. 1. *Ligyrus laevicollis* Bates. 2. *Ligyrus blatchleyi* Cartwright. 3. *Aphonus variolosus* (Leconte). 4. *Aphonus tridentatus* (Say). 5. *Aphonus brevicruris* Cartwright. 6. *Aphonus castaneus* (Melsheimer). 7. *Aphonus densicauda* Casey. 8, 9. *Phyllophaga yemasseei* Cartwright. 10. *Phyllophaga forsteri* (Burmeister). 11. *Phyllophaga tecta* Cartwright.

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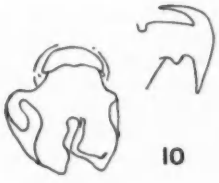

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erately coarsely, not closely punctate; suture sinuate, unevenly impressed, the sides much more deeply than the slightly impressed median angle. Head somewhat flattened; punctures similar but a little closer than on clypeus, separated by about one diameter or less. Pronotum less than twice as wide as long; sides crenate, widest slightly before the middle, arcuate to obtuse anterior angles, sinuate to right angled posterior angles; punctures about same size as on head but irregularly placed, separated by from one or less to as much as four diameters. Elytra more evenly, more deeply, and somewhat more finely punctate; only sutural costae distinct, others very faint. Mesosternum with very sparse punctures bearing fine hair. Abdomen finely sparsely punctate, the punctures with very short scarcely noticeable hairs; a distinct median longitudinal impression, the terminal and posterior of the penultimate segments slightly roughened with fine transverse granules. Pygidium convex with shallow, indistinct, coarse punctures. Upper spur of hind tibia moderately long, lanceolate, subacute; lower spur obliquely truncate, three-fourths as long as upper; end of tibia excavated. Tooth of claw near base and very small. Aedeagus as in figs. 8 and 9.

Female unknown.

Holotype taken at light, Yemassee, S. C., June 6, 1941, O. L. Cartwright.

Phyllophaga yemasseei keys to Horn's group VI, and is very closely allied to *P. debilis* (Lec.) from which it may be separated by the genitalia, by not having the small median denticle on the anterior margin of the terminal abdominal segment as in *debilis*, and by other minor differences.

Phyllophaga tecta n. sp.

Figure 11

Holotype Male.—Length 19.5 mm., width 10 mm. Elongate oval, shining, glabrous, castaneous. Antennae 10-segmented, rufo-testaceous, club slightly shorter than stem. Clypeus rather deeply emarginate, margin reflexed, surface quite closely punctate, suture sinuate. Head moderately punctate, the punctures slightly coarser than on clypeus and less close, particularly along suture. Pronotum three-fifths as long as wide, widest at middle, sides convergent anteriorly, sinuate to right angled posterior angles, margin crenate, surface shining, punctures still coarser and less closely placed, average separation one to two diameters. Sutural costae of elytra moderately strong and rather wide, discal obsolete, submarginal narrow, obsolete over basal third; surface shining, rather finely moderately closely punctate, middle of disc somewhat rugulose. Mesosternum finely punctate, covered with moderately sparse yellowish hair. Abdomen finely punctate, and with short appressed yellowish hair, median area flattened longitudinally, last two segments with a deep cup-like depression, the penultimate segment finely transversely granulate within the cup and noticeably elevated at the sides, terminal segment smooth within the cup. Pygidium rather sparsely finely punctate. Fixed spur of hind tibia strong, acute, and four-fifths as long as upper; upper thin, lanceolate, subacute, and about as long as first segment of

tarsi. Tooth of claw median, long, nearly right angled. Aedeagus as in fig. 11.

Allotype Female.—Length 18 mm., width 10 mm. Club of antennae slightly shorter than funicle, abdomen evenly convex, apex of pygidium more acutely rounded, both spurs of hind tibiae thin and lanceolate, otherwise similar to male.

Type and allotype collected at Gainesville, Fla., March 22 and 13, 1925, by T. H. Hubbell. Eighteen paratypes which vary in length from 17.5 mm. to 21 mm.; in width from 9 mm. to 11 mm., one from Bradenton, Fla., 3–8–38, W. Benedict, all others from Gainesville, Fla., March 12 to May 8, various years 1923 to 1929.

Paratypes deposited in collections of University of Kansas, M. W. Sanderson, Philip Luginbill, F. N. Young, and author.

Phyllophaga tecta is very close to *P. forsteri* (Burm.) but averages somewhat larger and the genitalia show a constant difference in structure.

Phyllophaga marginalis var. **insolita** n. var.

Holotype Male.—Length 18 mm., width 8.7 mm. Oblong, rather elongate, subdepressed, feebly shining to subopaque, dark brown, clothed with semi-erect, fine, rather close mixed short to moderately long hair. Antennae 10-segmented, stem subequal to club. Clypeus flat, emarginate; margin narrowly reflexed; surface coarsely, deeply, and closely punctate; suture sinuate, slightly impressed. Head with a narrow smooth area medially across occiput, otherwise punctate as on clypeus, the punctures bearing fine yellowish recurved hairs which are gradually longer toward the sides of the head. Pronotum not quite twice as wide as long, sides crenate, widest slightly back of middle, arcuate to anterior angles, slightly sinuate to posterior angles; surface coarsely, deeply and densely, in some instances almost confluently punctate, the punctures alutaceous within, and each bearing a fine anteriorly placed recurved hair, the length of the hair being from one to two times the diameter of the punctures. Elytral surface finely alutaceous, vaguely rugulose, and with fine, close, rather shallow punctures, each bearing a fine semi-erect hair of variable length; sutural and submarginal costae distinct, discal costae more or less obsolete. Mesosternum closely finely punctate, clothed with fine yellowish hair. Abdomen with moderately close fine punctures bearing fine short appressed hair; broadly depressed medially; penultimate segment with a short, strongly arcuate, finely roughened ridge at middle, the posterior edge shallowly emarginate; terminal segment with a median depression. Pygidium convex, with moderately close shallow medium punctures, and short appressed hair. Fixed spur of hind tibia rather broad, acute, two-thirds length of the upper which is thin lanceolate and acute. Tooth of claw median, strong, slightly recurved. Aedeagus as in typical *marginalis*.

Allotype Female.—Length 19.5 mm., width 10 mm. Similar to male in all respects except that the head and thorax seem even more roughly and more frequently confluently punctured; the pubescence of the elytra is slightly longer; the club of the antenna is shorter than

the funicle; the abdomen is convex; and the apex of the pygidium is more acutely rounded and convex. Genitalia as in *marginalis*.

All 17 specimens of the typical series were submitted by Dr. H. P. Loding and all bear the same label—Cheaha Mtn., Talapoosa Co., Ala. VI–7–40, Mus. Exp. Paratypes in collections of H. P. Loding, M. W. Sanderson and writer.

This subspecies may be associated with *marginalis* through its identical genitalia. Externally its appearance is quite distinct, the rough, very coarse, deep, and dense punctures of the thorax, together with the pubescence of the elytra, serve to distinguish it at once.

Ligyrus blatchleyi n. sp.

Figure 2

Holotype Male.—Length 24 mm., width 13.5 mm. Oblong oval, shining, rufopiceous, under surface and legs only slightly lighter. Head a little less than half as wide as thorax, rugulose except at occiput where the rugulose lines break into moderate punctures; mandibles bidentate; clypeus triangular, somewhat concave, sides narrowly reflexed, apex bidentate, the upturned teeth approximate, acutely rounded, base with a blunt tubercle midway each side of middle; front shallowly impressed. Thorax two-fifths wider than long, sides broadly rounded, anterior angles acute, posterior angles broadly rounded, front margin with median tubercle immediately in front of a shallow oval depression one-fifth width of thorax, punctures moderate and close, separated by one or two diameters in anterior and posterior angles, finer and closer toward apical tubercle, gradually sparser and much finer medially toward base, a small almost smooth area at middle of each side, the anterior depression with transverse wavy rugulosity breaking to moderate punctures posteriorly. Elytra two and one-third times as long as thorax, widest at posterior third, sutural and discal striae well marked, the coarse annular punctures of the striae and of the alternate wider intervals about equal in size and almost as closely placed, becoming slightly larger laterally, finer at the apex and on the first interval, interspersed sparse fine simple punctures throughout, the subapical and humeral umbones otherwise smooth. Prosternal postcoxal process moderately densely hairy, its apex flattened and nude anteriorly. Mesosternum finely closely punctate medially. Metasternum smooth at middle, coarse shallow alutaceous punctures at sides. Abdominal segments with a transverse row of setigerous punctures laterally, virtually impunctate medially, ciliated edge of terminal segment deeply emarginate leaving a wide depressed smooth apical margin at middle. Pygidium twice as wide as long, evenly moderately convex, base and sides scabriculate, middle and apex minutely punctate. Aedeagus as in fig. 2.

Allotype Female.—Length 21 mm., width 12 mm. Very similar to male except that the spur of the anterior tibia is much more slender, the tubercles at the base of the clypeus are absolete, the thoracic punctures are slightly finer, the pygidium is less convex, the pygidial punctures are much more conspicuous, being of moderate size, quite

close, and discernible even in the scabriculate basal part, to somewhat finer and less closely placed over the smooth apical part, and the terminal abdominal segment is not emarginate.

Holotype and allotype collected at Miami, Florida, June 25 and 30, 1933, by Frank N. Young. Fourteen paratypes, 8 males, 4 females, Miami, Fla., June 16, 22, 25, 30, 1933, F. N. Young; Ft. Lauderdale, Fla., May 24, 1928, D. M. Bates; Everglade, Fla., June, 1912, Wm. T. Davis Coll.; Savannah, Ga., June 15, 1937, P. W. Fattig; Charleston, South Carolina, June 7, 1933, J. P. DeVeaux, Jr.; and a pair of specimens reared at Cornell University from larvae collected at Englewood, Fla., by Dr. J. G. Needham.

The typical series varies in length from 21 to 25 mm., in width from 12 to 14 mm. Considerable variation in the size of thoracic punctures is evident in both sexes, being much finer in some specimens than others. Variation is also noticeable in the elevation and distance between the apical teeth and between the basal tubercles of the clypeus. On one somewhat deformed individual the apical teeth appear as a single binodose tooth. The extent of rugulosity within the apical thoracic depression is quite variable but is evident in all specimens.

I am grateful to Prof. J. J. Davis for comparing specimens with the type of Blatchley's *subtropicus* and for the loan of a specimen labeled *laevicollis* Bates from the Blatchley collection. The latter specimen from Everglades, Fla., collected by W. T. Davis, is included among the paratypes of *L. blatchleyi*.

Prof. Davis stated that *L. subtropicus* was darker, conspicuously larger, measuring about 25 mm. long and 14 mm. wide at base of wings (specimens of *L. blatchleyi* are as long!), mandibles bidentate with the outer tooth twice as large as the inner one (those of *blatchleyi* are about equal in size), apical clypeal teeth strongly acute and the notch between the teeth deep and broad and the teeth sharply upturned, tubercles of clypeal suture conspicuous, about 1½ mm. apart and the flattened area back of thoracic tubercle with sparsely placed fine punctures, similar to the rest of the thorax. Considering the rather wide variation exhibited in the series here considered a single species (*blatchleyi*), it would seem possible that *subtropicus* might be only an extreme variation of the same species; however, since none of the series shows the thoracic depression "with sparsely placed fine punctures similar to the rest of the thorax" and since Prof. Davis stated concerning *subtropicus*, "there is no question in my mind that it is distinct from the species you sent," I am presenting the above description.

I am indebted also to Dr. J. G. Arrow of the British Museum for comparisons of specimens of *blatchleyi* with the type of *L. laevicollis* Bates. In his opinion the species was distinct from *laevicollis* and was probably undescribed. A specimen of *laevicollis* from lower California, also compared by Dr. Arrow with the type, differs from *blatchleyi* in that the posterior half of the thorax except at the extreme sides is almost devoid of punctures, the apical thoracic area is rugulose but is only very slightly flattened instead of depressed, the first interval of elytra is smooth and lacks coarse punctures near the scutellum and along the sutural stria, and the aedeagus is distinctly different as shown in fig. 1.

Aphonus brevicruris n. sp.

Figure 5

Holotype Male.—Length 13 mm., width 9 mm. Pyriform oval, convex, shining, dark castaneous. Head convex, small, two-fifths as wide as thorax; clypeus shining, short, concave laterally, side margins reflexed, sparsely moderately punctate, reflexed subapical carina indistinctly tridentate, the middle tooth much higher, apical carina acutely rounded; front and sides of head with coarse sharp wavy interlacing rugulosity, the rugulae gradually more widely separated posteriorly, occiput smooth medially with a few scattered moderate punctures. Thorax convex, two-thirds as long as wide; sides evenly weakly arcuate, converging to acute apical angles, posterior angles obtusely rounded, basal lobe distinct but weak; punctures strong and close-set in and back of the anterior angles, gradually finer and less numerous towards middle, sides and base, the punctures being very fine and sparse over the basal lobe; excepting a few punctures at anterior third the median line rather broadly impunctate. Scutellum longer than wide, smooth, feebly concave. Elytra not quite as wide as long, wider than thorax at base; punctures coarse, shallow, umbilicate, the series somewhat more deeply impressed on the disc, and more noticeably annular toward sides, smaller on apical declivity, surface of lateral fourth and apex rugose with punctures more or less confused. Pygidium strongly convex, nearly twice as wide as long, minutely scabriculate throughout, apical beading strong and equal. Posterior legs short and stout, femur three-fifths as wide as long; tibia shorter than femur, its widely flared apex more than half as wide as full length of tibia; tarsi one-fifth longer than the tibia, the basal segment externally drawn out in a long tooth or spur half the length of the second segment.

Aedeagus distinct (fig. 5).

Female unknown.

The unique holotype collected at Austwell, Texas, May 20, 1941, by Woodrow Goodpaster. *Aphonus brevicruris* superficially resembles large dark specimens of *castaneus* (Melsh.) but is easily recognized by the short heavy tibiae. The aedeagus is quite different from those of the other four species previously found in the United States. All are shown in figures 3 to 7.

OBSERVATIONS ON THE EARLY STAGES AND LIFE HISTORY OF THE GRASS PUNKY, ATRICHOPOGON LEVIS (COQUILLETT)[1]

(Diptera: Heleidae)

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AND

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INTRODUCTION

Atrichopogon levis was described by D. W. Coquillett (1901) from a single female specimen collected at Marlboro, Maryland. Malloch (1915) recorded the species as the commonest of its genus (*Ceratopogon*) in Illinois and mentioned additional records for New York and Michigan. He figured also details of the male antennae and genitalia. Johnson (1925) recorded the species from Massachusetts, Rhode Island, and Connecticut. Up to the present time, we have no published information on the early stages or adult habits of the grass punky.

In August, 1941, Miss Dorothy Clum collected two larvae from algae growing on the surface of damp soil. Their structural features quite readily placed them with known larvae of *Atrichopogon*, but structural details likewise clearly separated them from any of the three American species whose immature stages, excluding eggs, were known. Immediate steps were therefore taken to secure an abundance of material for rearing and observation. Both authors carried on detailed observations at Put-in-Bay, located on South Bass Island, in western Lake Erie; additional observations were made by the senior author at Oxford, and by the junior author at Covington, Ohio. The senior author in 1940 had received a single preserved specimen of *Atrichopogon levis* in the third larval instar from Dr. Philip C. Stone but, since the stage had not been described, the specimen remained unidentified until the present work was nearly complete. Upon re-examination it was readily recognized. To Dr. Stone then must go credit for the original discovery of the larva.

The writers wish to express their indebtedness to Dr. O. A. Johannsen for his valuable suggestions and for his aid in identifying the species treated in this paper; to Dr. C. E. Taft for his determinations of algae; and to Dr. C. F. Walker for information concerning the vertebrate fauna of South Bass Island.

METHODS

Petri dishes and stender dishes were employed to make life history studies in the laboratory. In general, only one individual was kept in a dish so that its development could be accurately followed. The bottom of each dish was lined with four thicknesses of moist towel paper. On this was placed a piece of earth covered with algae and

[1]Contribution from the Franz Theodore Stone Laboratory, Put-in-Bay, Ohio.

having a total surface of about one-half to one square inch, a size which proved to be adequate for the complete development of an individual from egg to adult. The dishes were kept covered except when the material was being studied. Generally they were placed in windows with a northern exposure, or on laboratory tables, out of direct sunlight. Under those circumstances larvae usually remained strictly on the earth in the dish. Occasionally they would move out of sight for a time, only to reappear later on the soil surface.

Early stages fared well under laboratory conditions described above. Mortality was exceedingly low, having been highest in the pupal stage. It was found possible to collect eggs and carry them through to the adult condition in the dishes. Careful observations were made on larval instars and on other details of the life history. Field observations were necessarily limited because of restrictions imposed by the microscopic nature of some of the stages with which we were dealing.

DESCRIPTIONS OF EARLY STAGES

Egg (fig. 1).—Smooth, subshining, black. About 3.6 to 4.2 times longer than greatest width, depending on view. Slightly curved. Length, 0.37 to 0.41 mm.

Larva (figs. 2; 4–7).—The larval stage is represented by four instars. Although the instars are described below in logical order, the first three are covered only insofar as their features differ from the fourth or from each other.

The first instar (fig. 4) differs from all others in that the body projections are hardly evident, even setae being poorly developed. As in the second instar, there is only one seta on each of the second thoracic projections. Length, 0.38 to 0.87 mm. Width of head capsule, 0.08 to 0.10 mm.

The second instar (fig. 5) differs from third and fourth instars in the following respects: projections on the first thoracic segment very short; only one seta on each of the second thoracic projections. Differs from fourth instar in that the projections on the eighth abdominal segment are simple. Length, 0.77 to 1.3 mm. Width of head capsule, 0.11 to 0.13 mm.

The third instar (fig. 6) differs from fourth instar in the following respects: projections on the first thoracic segment hardly more than twice as long as their diameter; projections on the eighth abdominal segment simple; second seta on the projections of second thoracic segment only about a third as long as the first. Length, 1.3 to 2.0 mm. Width of head capsule, 0.14 to 0.19 mm.

Fourth Instar (figs. 2 and 7).—Head with ventrally directed mouthparts. Four pairs of cephalic hairs distributed as follows: just posterior to the bases of the antennae, on the front between the antennae and the corners of the mouth, low on the cheeks at the level of the eyes, low and posteriorly on the cheeks; the last three pairs form a sort of ring at or just below the middle of the head. Antennae conspicuous, quite rigid, horn-like, on well developed tubercles; composed of two

EXPLANATION OF PLATE I

FIGURE 1. Eggs, several views. 2. Fourth-instar larva, lateral view. 3. Pupa, lateral view.

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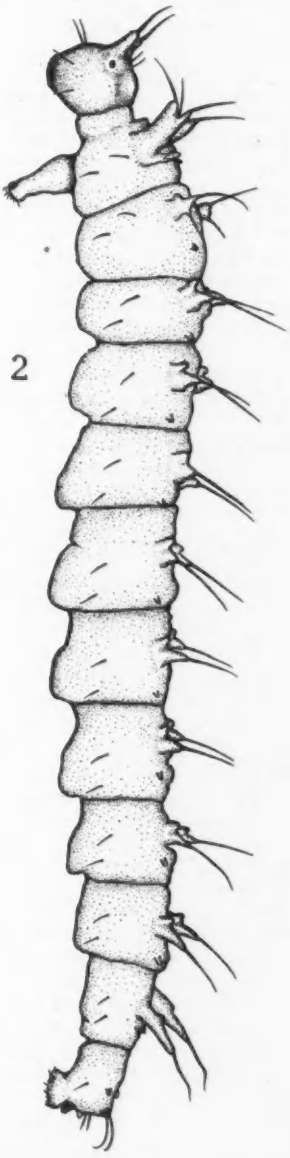

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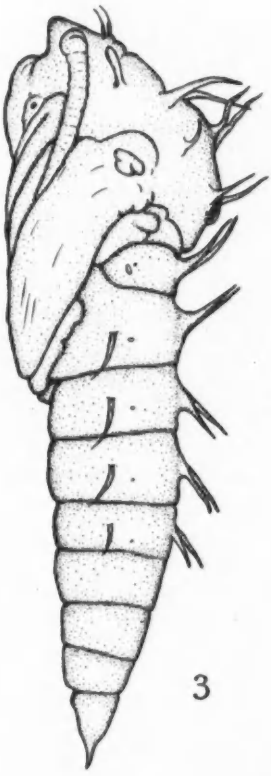

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segments, the terminal segment being microscopic. Eyes undivided, at the bases of the antennal tubercles. Dorsum of head particularly ornamented with microscopic nodules.

Body segments nearly circular in sectional view, not conspicuously depressed. Each body segment except the last with a pair of conspicuous dorso-lateral projections, those on the first and second thoracic segments each bearing two setae, the rest only one. Projections on the first thoracic segment more than twice as long as their diameter; projections on the eighth abdominal segment tending to be compound. Second seta on the projections of the second thoracic segment about half as long as the first. Each body segment except the last bearing a pair of small projections behind the large setiferous projections and provided laterally with two hairs. Terminal segment with one hair on each side and two terminal hairs; also a pair of dorso-terminal setae on poorly developed projections. Body ornamented with microscopic conical nodules.

Anterior prolegs elongate, fused to near apex; posterior prolegs short.

Color of living larva commonly uniform dull yellow, greenish yellow, or yellowish brown. Head more or less translucent to black, becoming progressively darker as the stadium progresses. As the time of pupation approaches, a median dorsal yellow body line may appear. Later, the yellow may be extended so as to give the following pattern: first thoracic segment yellow; middle of the other thoracic and the abdominal segments yellow, the dorso-lateral margins between the projections orange-brown; eighth abdominal segment with orange-brown areas continuous between the right and left dorso-lateral projections which seem to be connected by a sclerotized area; ninth abdominal segment above wholly orange-brown and sclerotized.

Length, 2.3 to 3.3 mm. Width of head capsule, 0.20 to 0.28 mm.

Pupa (figs. 3 and 8).—Thoracic dorsum with five pairs of bristles, as follows: two dorsal pairs nearly forming a square on the disc of the scutum; an anterior pair between the anterior dorsals and the respiratory trumpets; a smaller lateral pair between the anterior dorsals and the wing pads; and an exceedingly inconspicuous, decumbent, transparent posterior pair behind and mesad of the posterior dorsals with the tips lying between the bases of the posterior dorsals.

Respiratory trumpets boot-shaped, clavate, flat, or cylindrical, depending on view.

First to fifth abdominal segments each with a pair of dorsal bristles, the first and second pairs directed cephalad, the third to fifth pairs directed caudad. Second to fifth abdominal segments each with a pair of lateral bristles. Last four segments without bristles. Terminal segment forked, the projections directed posteriorly. Larval skin regularly remaining attached to the pupa and covering the abdomen posterior to the middle of the sixth segment.

Color of living pupa dull yellow to brown.

Length, 1.7 to 2.5 mm.

EXPLANATION OF PLATE II

FIGURE 4. First-instar larva, dorsal view. 5. Second-instar larva, dorsal view. 6. Third-instar larva, dorsal view. 7. Fourth-instar larva, dorsal view. 8. Pupa, dorsal view.

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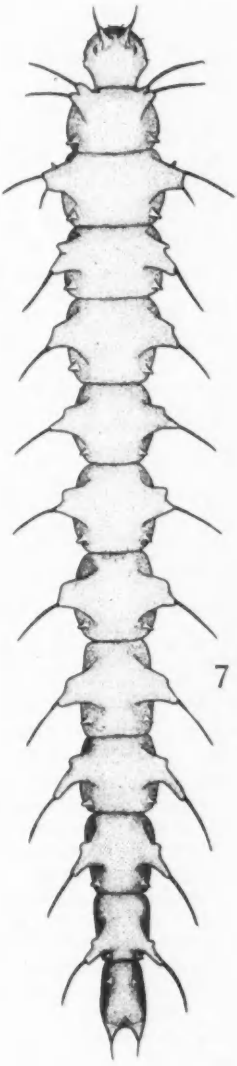

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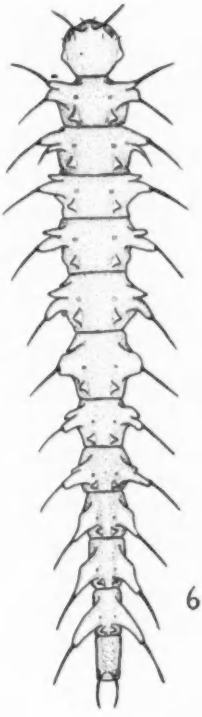

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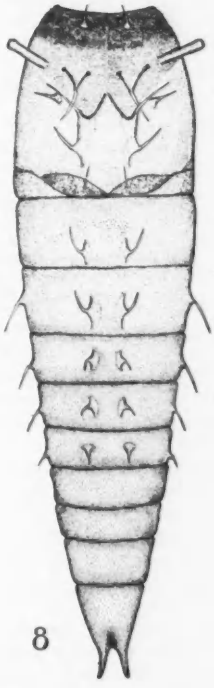

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EGG

KEYS TO NORTH AMERICAN SPECIES OF ATRICHOPOGON

Atrichopogon levis is the fourth American species for which larvae and pupae have been described. It may be noted here also that the early stages of this grass punky do not resemble at all closely those of any known Palaearctic species. Keys to the known Nearctic species are given, to some extent after Thomsen (1937).

KEY TO LARVAE

1. First thoracic segment without conspicuous projections or processes; anterior abdominal segments with two longitudinal dark lines 2
1′. First thoracic segment with conspicuous processes; dark, parallel, dorsal lines absent 3
2. Black areas present dorso-laterally on first thoracic segment and laterally on eighth abdominal segment ..... **websteri**
2′. First thoracic and eighth abdominal segments without differentiated black areas ..... **fusculus**
3. Projections in some cases more than twice the diameter of the body segment on which they are located; processes on first thoracic segment not more conspicuous than those on second; abdomen conspicuously more bristly than thorax ..... **peregrinus**
3′. Projections including setae in no case twice the diameter of the body segment on which they are located; processes on first thoracic segment more conspicuous than those on second; abdomen not conspicuously more bristly than thorax ..... **levis**

KEY TO PUPAE

1. Thorax with twelve bristles; last segment with projections at right angles to segment 2
1′. Thorax with six or ten bristles; last segment with projections directed posteriorly 3
2. Two thoracic bristles ending in a spine; respiratory trumpets boot-shaped, **fusculus**
2′. Six thoracic bristles ending in a spine; respiratory trumpets without heel-like projection near base ..... **websteri**
3. Thoracic bristles six; color largely black; anterior abdominal segments with branched lateral projections ..... **peregrinus**
3′. Thoracic bristles ten (one pair very inconspicuous); color brown; anterior abdominal segments with simple lateral bristles ..... **levis**

BIOLOGY

Length of the Life Cycle and Its Components.—On the average, development from the laying of the egg to adult emergence requires about twelve or thirteen days under apparently favorable summer laboratory conditions. We have no information on the length of the preoviposition period. There is of course considerable variation in the length of the different stages. Speed of development seems to be greatly modified by environmental influences (see below). A reasonable estimate places the average length of the egg stage at about three days. In one case all of a series of twenty eggs, which were collected out-of-doors and segregated, had hatched within two and one-half days; fourteen had hatched within one day. The first three larval instars each require about one and one-half days, with variations noted between one and three days. The fourth larval instar however is longer, usually requiring about two and one-half days, with variations ranging principally between two and four days. The pupa likewise requires about two and one-half days with a range almost exactly the same as that of the fourth larval instar.

Oviposition and Hatching of Eggs.—*Atrichopogon* species of the Palaearctic region for which information is available lay eggs in masses, in aquatic situations. Nothing seems to have been published regarding the eggs of American species. It is therefore doubly interesting to note that females of *Atrichopogon levis* deposit their eggs singly on soil covered with algae, in shaded situations. If such soil is examined under the microscope, eggs may be found lying flat on the surface. Eggs have never been found concealed or embedded in any way. Unhatched eggs are firm and can readily be moved around with a fine dissecting needle. After an egg has hatched, the shell generally collapses and lies flat against the soil, but occasionally a shell will retain the original form and may then appear like an unhatched egg. Therefore eggs under observation were always gently probed to determine whether or not they had hatched.

Larval Feeding.—Soon after hatching the larvae begin feeding on the superficial algae. They grow quite rapidly, almost invariably showing a measurable increase in length within a period of two or three hours except near the time of ecdysis. All larval instars take the same food and feed in the same manner. Larvae viewed from the side could readily be seen to feed on the algae covering the soil in the dishes. An analysis of the stomach contents of several larvae revealed *Oscillatoria*, *Rhizoclonium*, and *Navicula*. Larvae generally move around slowly over the algae, feeding as they go. At each slight hesitation, a larva crops off the plants within its immediate reach. In this manner indistinct feeding trails are left among the soil algae. More distinct are the fecal trails which are almost continuous ridges of moist glistening material having a greenish or brownish cast and a varying diameter.

An analysis of surface material found where larvae were feeding revealed *Tetraspora* as the dominant algal genus; other genera recorded are *Lyngbya*, *Rhizoclonium*, *Chlamydomonas*, *Oscillatoria*, *Navicula*, *Pandorina*, *Trachelomonas*, *Oedogonium*, *Stichococcus*, *Chroococcus*, and *Spirogyra*.

Larval Behavior.—Larvae in general move around slowly over the soil surface in feeding but are otherwise inclined to be inactive, except possibly when they are reacting negatively to light. Later-instar larvae particularly have a habit of resting in shallow depressions in the soil where they may remain for long periods without moving, particularly in the latter part of the fourth stadium. In such resting individuals the anterior end sometimes jerks about nervously. Occasionally larvae were found with only their heads protruding from under the edges of partially embedded leaves or from small soil crevices. Now and then larvae were observed to be very dirty, as though they had been in the mud. It seems altogether probable that they sometimes actually burrow in the soil. Once it was suspected that they burrowed in the soil to molt, but that is certainly not always, if ever, the case. They molt on the soil, leaving the cast skin at the surface.

Observations on Habitat.—It may be noted here that all areas which we found supporting stages of *Atrichopogon*, whether in vineyards, near puddles, or along streams, are subject to occasional or periodic flooding and are more or less protected from drying out by shade from woody vegetation. Such intermittently wet areas support the growth of ter-

restrial algae and many normally aquatic ones. As these locations dry out, the algae continue to exist in a resting state.

The larvae originally found by Miss Clum were located under a clump of small willows growing in a rather poorly drained area in a vineyard. The ground at the time was moist and covered with a growth of algae.

Many larvae were also located in the general area of one of the sinks on South Bass Island. The hole of the sink is plugged to such an extent that water is only gradually lost through seepage and evaporation, so that a sizeable spring pond is gradually reduced to a small late-summer puddle. In that area, larvae were at first found in numbers along a cow-path under a clump of willows; they were on occasion particularly abundant in the cow-tracks where the ground was somewhat more moist than elsewhere. As the season progressed and the soil became more and more dry, larvae became increasingly scarce in the cow-track area under the willows but were found more plentifully under clumps of small willows nearer the center of the sink. Later, examination of the soil near the water revealed many eggs as larvae became scarcer under the clumps of small willows. Thus seems to be indicated an *Atrichopogon* successional movement in the direction of the center of the sink as conditions became increasingly dry.

Moisture Relations.—Habitat observations detailed above suggest that adults are probably very sensitive to moisture conditions in laying eggs.

Laboratory observations indicate that the larvae of the grass punky are not inclined to be aquatic. If the soil on which the larvae are being reared is made rather moist so that an evident water film covers the algae, the larvae invariably crawl up on the sides of the dish. This suggests that they would very quickly be driven out of an environment with even a slight excess of moisture.

However, habitat observations, as indicated above, suggest that dry soil is unfavorable for larvae, perhaps only because it does not promote algal growth. Attempts to collect larvae over a period of weeks demonstrated that, as the soil dried out, larvae became increasingly difficult to find, particularly the early instars, until finally only a few relatively inactive individuals could be found. Where conditions seemed favorable, early- and late-instar larvae were on occasion collected from the same cow-track.

Temperature Relations.—No accurate temperature records were kept but we could not help noticing a marked influence of temperature on rate of development. A series of cool days invariably impeded development in the dishes. On the other hand, warmth seemed to speed up development. On one occasion, two larvae were transported on a warm day about 130 miles in vials placed in the glove compartment of an automobile. One of the larvae died, but the other passed through the third instar in about twenty-four hours, the shortest time recorded for that instar.

Pupation and Pupal Activities.—Pupation occurs on the soil surface. As in other species of *Atrichopogon*, the larval exuvium remains attached to and covers the posterior end of the pupal abdomen. On a flat surface, pupae lie with the ventral side down. In the dishes, under laboratory conditions, pupation often occurs next to a piece of plant

material or next to the earth on the paper or at the outer edge of the towel paper. Occasionally pupae are found attached to bits of dead vegetation projecting from the earth.

Pupae are usually inactive and show no tendency to move. However, if the anterior end is touched lightly with a dissecting needle, the body except for a few posterior segments is tossed backward vigorously, sometimes to an extent of more than ninety degrees, and is held there for about half a minute; then it suddenly jerks back into its original position against the substratum.

Habits of Adult.—The senior author has taken adults of *Atrichopogon levis* in almost unbelievably great numbers, particularly in Illinois. So abundant is this species in short grass in Illinois that we came to call it the "grass punky," a common name which has been adopted in this paper. The species abounds in the short grass of parks, lawns, cemeteries, and roadsides but is by no means confined to such locations. Adults are likewise abundant in some Ohio localities. Frequently males have been taken from swarms which appear with considerable regularity at about the time when the sun is approaching the horizon, or at other times providing a roughly equivalent light intensity. Swarms may occur in the same limited area evening after evening and year after year. Swarming territories swept just after dark, when the punkies are no longer visible, may yield both males and females; the implication is that mating occurs under such circumstances. Swarms commonly center about two or three feet from the ground but may rise considerably higher.

Although most of the observations reported in this paper were made at Put-in-Bay, the adults seem to be rather rare in the Put-in-Bay region. Cemeteries, lawns, and a variety of other situations have been swept systematically, usually without success. Lighted store windows in the downtown area, which are in many places productive on dark nights, have at Put-in-Bay given completely negative results, although thousands of Tendipedidae crowded about some of the lights. Nor have adults been seen swarming at Put-in-Bay. Adults are very common at Oxford, where they have been taken as early as May 14 and as late as October 21. Malloch (1915) records them for Illinois from April 18 to November 24.

Adult males and females have been found flying in rather broad daylight above moist mud encrusted with algae. It has not been established however just when oviposition takes place. Such mud may be so moist as to show no cracks; in other cases, drying out may have proceeded to the extent that one-eighth inch cracks are visible. Adults have been collected along streams as well as near stagnant water.

The writers have been unable to learn anything about the food habits of the adults.

Overwintering.—Attempts have been made to find stages of the grass punky in winter but results have been negative. After the early stages had been worked out, the senior writer happened to recall receiving from Dr. P. C. Stone in 1940 an unknown larva which seemed to belong to the genus *Atrichopogon*. Upon checking this individual it was found to be a third-instar larva of *A. levis*. We are deeply indebted to Dr. Stone for information concerning the circumstances surrounding the discovery of that larva. It was taken from the nest of the prairie

meadow mouse, *Microtus ochrogaster* (Wagner), in Urbana, Illinois, on January 22, 1939. Dr. Stone states that another specimen was collected from grass above the nests on November 22, 1939, and suggests that larvae found in the nests "had probably been brought into the nests on the grass nest material." We know then that third-instar larvae occur in midwinter. The fact that Dr. Stone in his careful study of nesting material reported no other stages suggests that the larvae are inactive. A necessary association between *A. levis* and *M. ochrogaster* must not however be assumed, for *Microtus* is not known to occur on South Bass Island where larvae were located in some abundance. The house mouse, *Mus musculus* L., and the white-footed mouse, *Peromyscus leucopus* (Raf.), are nevertheless present on that island. Possibly there is a winter connection between the grass punky and rodents.

SUMMARY

1. All of the early stages of *Atrichopogon levis* are terrestrial.

2. The period between oviposition and adult emergence under favorable conditions is about twelve or thirteen days, the duration of the respective stages being roughly as follows: egg, three days; larva, seven days; pupa, two and one-half days.

3. Eggs are laid singly and flat on the surface of moist soil covered with algae, in shaded situations.

4. Eggs are black, subshining, slightly curved, and average 0.39 mm. in length and 0.10 mm. in width.

5. All larval instars feed on algae.

6. There are four larval instars ranging in length from 0.38 to 3.3 mm. and with average head capsule widths as follows: first, 0.09 mm.; second, 0.12 mm.; third, 0.17 mm.; fourth, 0.23 mm.

7. The full-grown larva differs from other known American *Atrichopogon* larvae in having prothoracic projections which are well developed and distinctly more prominent than are the mesothoracic projections.

8. Inasmuch as larvae are dependent on algae on the soil for food, a given environment is likely to remain favorable to them for only a limited period of time.

9. Pupation occurs at the soil surface where pupae remain essentially in an inactive condition.

10. Pupae average 2.2 mm. in length and differ from other known American *Atrichopogon* pupae in having ten thoracic bristles.

11. Adults may be exceedingly abundant in the short grass of lawns by day. Swarming commonly occurs at dusk, a few feet from the ground.

12. The grass punky probably overwinters as an inactive larva.

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CORRELATION BETWEEN MANDIBULAR MORPHOLOGY AND FOOD SPECIFICITY IN GRASSHOPPERS[1]

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INTRODUCTION

The adjustment between food and mandibles of biting insects is so definite that entomologists find little of phylogenetic value in the various mandibulate patterns (Walker, 1933, p. 325). The specialization of mouth parts for different foods is a basic fact recgonized in all entomological study (Snodgrass, 1935, p. 280). Food specificity among insects has for some time been a major problem with many experimental, economic, and field entomological investigators. Brues in a series of studies has emphasized the biological significance in insect food adaptations, especially for studies in evolution.

The morphology of the mandibles and other mouth parts of the Orthoptera and related insects has been investigated by Nininger (1915), Yuasa (1920), Golden (1925), Snodgrass (1928), Petrov (1905), in Uvarov, 1928; the paper by Petrov has not been seen by the writer; Walker (1933), *et al.* Uvarov (1928, p. 4) calls attention to the marked variability of the mandibulate "teeth" among the different species of the Acrididae.

In the literature at hand, however, no mention is made of special adaptations of mandibles by phytophagous grasshoppers to different types of vegetation or plant parts, such as grasses, forbs, buds, flowers, and seeds. The fact that there is deep-rooted misinformation to the effect that grasshoppers eat "everything green," or at least that all grasshoppers eat grass, may have inhibited inquiry into the obvious evolution of acridian mandibles to variations in host plant tissues.

Students of mammalian evolution and adaptation have long emphasized the adjustment of teeth to varying types of vegetation. Scott (1924), in discussing the history of herbivorous land mammals, points out that "such teeth imply that their possessors must have fed habitually upon a softer less abrasive diet than grasses, probably leaves of soft shoots of trees and bushes and other succulent vegetable sub-

[1]The term grasshopper in this paper follows the usage of many American authors and includes the Acrididae (short-horned grasshoppers) and the Tettigoniidae (long-horned grasshoppers).

[2]The writer wishes to thank Dr. Eleanor B. Scott and Dr. Gordon Alexander for reading the manuscript and making helpful suggestions. He is indebted to Dr. J. R. Parker for suggestions and literature, to Robert E. Pfadt and Roy F. Fritz for the use of their unpublished notes and records dealing with food preferences and subsistence foods of grasshoppers. My thanks are due to Ruth Maxwell Sanders for drawings of figs. 1 and 2, and to Kisa Noguchi for drawings of figs. 3 and 4. Helpful technical assistance has been given by Mary N. Isely, Tarver Morris, Walter B. McCall, and Martha Orr.

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stances." Botanical authors call attention to the compact leaf tissues of grasses composed of epidermis, sclerenchyma, and encased vascular bundles. Dr. Francis Ramaley in a letter to the writer (June 20, 1941, Boulder, Colorado) emphasized plant tissue differences, "Both stems and leaves of grasses contain much more silica than the corresponding parts of broad-leaved herbs. Grass stems have, in nearly all cases, the sub-epidermal sheath of sclerenchyma, and this as well as the epidermis and the hypoderma is usually highly silicified. Broad-leaved plants do not have as much sclerenchyma in their stems as grasses. The leaves have almost no silica."

FOOD SPECIFICITY

In earlier papers the writer has shown that many of the common species of grasshoppers (Acrididae and Tettigoniidae) of north-central Texas are selective feeders and that the Acrididae are for the most part strictly oligophagous. Since the mandibles are the principal biting and chewing organs of these grasshoppers, it has seemed worth while to investigate the adaptations to different types of vegetation, not only of the acridians feeding on grasses and forbs, but also of the plant-feeding and predaceous insect-eating Tettigoniidae. Preliminary studies were reported (abstracts, Isely and McCall, 1938; Isely, 1938b, 1941b). The present paper, which is a direct sequel to my published food preference researches, has awaited further field observations and cage testing of grasshopper food preferences and food subsistence diets.[3]

Previous cage studies involving forty species of the Acrididae have indicated that these short-horned grasshoppers fall roughly into two nearly equal groups, the grass feeders and the forbs feeders (Isely, 1938a, p. 586). A number of acridian species, while belonging primarily to one group or the other, are found to be mixed feeders, eating both forbs and grasses. Usually the mixed feeders may further be subdivided into (1) forbs-grass eaters and (2) grass-forbs eaters, according to whether first preference and subsistence food plants are found among the forbs or the grasses.

The fact that grasshoppers need specific diets for maximum longevity and fecundity has been demonstrated by several investigators, especially by the researches of Carothers (1923), Criddle (1933), Isely (1938a, 1941a), and Sanderson (1939). The cage studies for the present work and the unpublished experimental records of Pfadt[4] (1940, 1941) and Fritz[5] (1940) further emphasize the importance of food specificity for

[3]New data based on further investigations by the writer and not previously reported (Isely, 1938a and 1941a) are herein briefly summarized and are referred to as "summers 1939, 1940, 1941."

[4]Unpublished notes by Robert E. Pfadt, employed cooperatively by the Wyoming Experiment Station and the Bozeman Laboratory of the Bureau of Entomology and Plant Quarantine. The progress reports covering Mr. Pfadt's investigations for the summers of 1940, 1941 are on file at the Wyoming Experiment Station and the Bozeman Laboratory. These records were made available to the writer through the kindness of Professor C. H. Gilbert, Dr. J. R. Parker, and Mr. Pfadt and are referred to in this paper in the same way as other "Literature Cited" (Pfadt, 1940 or 1941).

[5]Mr. Roy F. Fritz, of the Kansas Experiment Station and the Garden City Area, has also kindly provided me with a summary of his "Food preference tests with *Aeoloplus turnbulli bruneri* Caudell" which were conducted in the Garden City Area, summer 1940.

optimum individual grasshopper maintenance, reproductivity, and species survival. The Tettigoniidae have not been as extensively tested as to their food preferences as have the Acrididae, but their diet requirements are also found to be specific. Certain species of the Tettigoniidae (Isely, 1941a) are found to select forbs or their flowering parts as food; others are wholly predaceous; and several species feed chiefly on the seeds of grasses.

MORPHOLOGY OF MANDIBLES

The asymmetry of grasshopper mandibles and the fact that the left mandible overlaps the right have been discussed and figured by Snodgrass, Uvarov, and others. The differentiation of the mandibles in biting and chewing insects has been emphasized by Metcalf (1929). For the present report the morphology of the mandibles of over one hundred and ten species of Acrididae and Tettigoniidae were macroscopically and microscopically examined. The parts of the incisor and molar lobes of these mandibles were checked for their gross histology. The mandibles of a number of individuals of several species were examined to note variations within the species; permanent mounts of mandibles were made; and the structures of the jaws of the several instars were studied and compared. For most species, however, the mandibles of only two or three specimens were examined from temporary mounts in water, alcohol, or plastic. To make the data on food specificity and mandibular correlation as complete as possible, all available records of food preference experiments of specific species of grasshoppers have been carefully checked.

MANDIBLE PATTERNS OF THE ACRIDIDAE

REPRESENTATIVE MODELS

Brachystola magna (Girard).—The morphology of the biting jaws of *B. magna*, the western lubber, also called the jumbo grasshopper, is selected as representative of those species which feed primarily on forbs and whose maintenance requires a diet made up of forbs. The chief morphological features of the jaws of *B. magna* are well depicted in fig. 1. The characteristic asymmetry and the fact that the left mandible overlaps the right is indicated in the anterior-ventral view (fig. 1, RA and LA). The left incisor lobe of *B. magna* is distally marked along the cutting edge by four well-defined dentes (ID). Only three dentes show prominently in the cutting edge of the right incisor lobe (RA), as dens No. 4 is smaller and back of No. 3. The mesial molar lobes likewise have several dentes which interlock in the chewing process. In comparison with mammalian tooth patterns (Scott, 1924), the molar areas of typical forbs feeders may be described as mastodontic. The molar area of the left jaw of *B. magna* is usually formed by four dentes surrounding a concavity in which two smaller denticles appear (fig. 1, LM). The general pattern of the molar lobe of the right jaw is well pictured in fig. 1. Six dentes of varying size surround the concavity of the right molar area (fig. 1, MD, ML). In chewing and triturating the leafy forbs these molar denticles of the right and left jaws are interspaced so as to form an efficient masticatory mechanism for eating the leaves, buds, and stems of the broad-leaved plants which constitute their diet.

B. magna is characterized by Hebard (1931) as belonging to the plains fauna of western U. S. extending from Texas to Montana. The writer has collected the western lubber on the western border of north-central Texas, in the Panhandle, and in the Trans-Pecos. Parker (1933) lists *B. magna* as one of the minor economic acridian species. In Texas, however, it is known at times to do considerable damage to cotton. In my cages *B. magna* fed by preference on such forbs as *Gossypium* (cotton), *Gaillardia*, *Ambrosia*, *Helianthus*, *Lactuca*, *Parthenium*, and other coarse weeds and garden plants. Among the weeds refused were *Amaranth*, *Croton*, *Euphorbia*, *Lepidium*, *Monarda*, *Solanum*, and *Verbena*. Young corn and succulent weed grasses were eaten, but in much smaller quantity when compared with palatable forbs. The feces in the cages containing grass were always sparse, dry, and light. Mature native grasses including *Andropogon*, *Sporobolis*, and *Buchloe*, as well as mature exotic Johnson and Bermuda grasses, were only nibbled. Four males placed in a cage June 19, 1941, and supplied regularly with mature grasses all died on the ninth day,

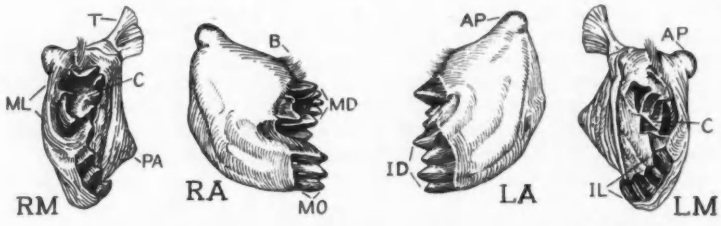

FIGURE 1. Forbivorous mandibles of *Brachystola magna* (Girard). RM, right mandible, mesial view; RA, right mandible, anterior-ventral view; LA, left mandible, anterior-ventral view; LM, left mandible, mesial view. The mesial views are secured by turning the mandibles out from anterior-ventral position. AP, anterior articular process; B, brustia; C, concavities of molar areas, formed by molar dentes; ID, incisor dentes; IL, incisor lobes; MD, molar dentes; ML, molar lobes; MO, margin of overlapping by left mandible; PA, posterior articular process; T, tendon adductor muscles.

June 28. In a second cage two pairs of *B. magna*, even when supplied with succulent grasses and corn, soon died and the eggs of dissected females apparently had deteriorated. In cages which were supplied with palatable forbs, other pairs of *B. magna* were feasting greedily, copulating, and ovipositing. There can be no doubt that, while *B. magna* will at times feed on corn and young grasses, perhaps even to the extent of economic damage, it requires a diet of a limited number of forbs for its successful maintenance and fecundity.

The avidity with which *B. magna* feeds on fallen comrades crushed by passing automobile or wagon wheels has been given as evidence that the species is predaceous and carnivorous. This suspicion is not confirmed by cage observations under starvation pressure.

Mermiria maculipennis Bruner.—This prairie acridian was chosen as a typical representative of the graminivorous species. Its food preferences were thoroughly tested by the writer (1938a). This species

quickly starved on a cage diet of fresh forbs which represented the favorite host plants of the forbivorous acridian species on the insectary shelves. The mandible patterns are well represented in fig. 2. The contrast with *B. magna* is striking. These differences are well shown in the anterior-ventral views of the molar lobes. The distal cutting edge of the left incisor lobe (fig. 2, LA) is more continuous than the jagged cutting edge of the incisor lobes of the forbs feeding *B. magna*. The four incisors fit closely together and are marked off by shallow grooves. The left jaw only slightly overlaps the right (RA) and the distal edge of the right incisor lobe is beveled (BV) to meet the incisor edge of the overlapping left lobe. The poorly defined individual dentes of the incisor lobe of the right mandible of *M. maculipennis* are indicated by a roughened row of denticles on the distal incisor edge. The individual incisors are barely indicated by shallow grooves on the outer concave surface of the right incisor lobe. The molar areas (ML) are likewise distinctive and different from the molar lobe surfaces of *B. magna*. Ridges and furrows (RF) make up the grinding surfaces of the broad mesial molar

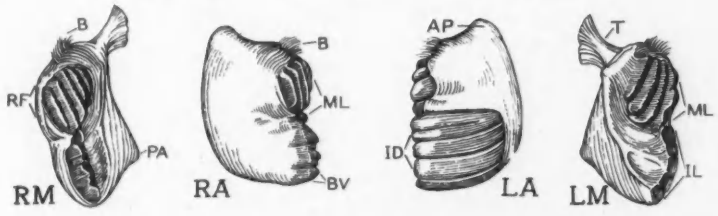

FIGURE 2. Graminivorous mandibles of *Mermiria maculipennis* Bruner. RM, right mandible, mesial view; RA, right mandible, anterior-ventral view; LA, left mandible, anterior-ventral view; LM, left mandible, mesial view. BV, beveled edge where left incisor lobe overlaps right incisor lobe; RF, ridges and furrows characteristic of molar pattern of graminivorous species; other parts as in fig. 1.

lobes of these grass feeders. When compared with mammalian tooth structure the graminivorous species may be described as mammoth-like in their molar patterns. While *M. maculipennis* is typical of the grass feeders, there are several other species both of the Acridinae and the Oedipodinae which have more highly specialized graminivorous mandible patterns. Frequently in these species the incisor dentes are entirely fused and form a continuous cutting edge. The furrows are shallower and the ridges less evident than those of the mandibles of *M. maculipennis*.

In Texas, *M. maculipennis* is one of the most characteristic of the prairie grasshoppers and, in favorable habitats, one of the most abundant. Rehn (1919, p. 107) remarks that "The occurrence of this species as a whole, as throughout the genus, is governed by the distribution of grass patches or continuous grass prairie." In north-central Texas, large populations of *M. maculipennis* are frequently found in the few remaining prairie grass pastures where conservative grazing has been practiced. It is worthy of notice, however, from the food pref-

erence viewpoint, that the writer's field records show *M. maculipennis* reaching population peaks in this area (north-central Texas) in a mixed growth of exotic grasses, Johnson and Bermuda.

Melanoplus differentialis (Thos.).—This species, frequently called the yellow grasshopper, is the most important economic acridian of north-central Texas. The food habits of *M. differentialis* have been critically studied by experimental zoologists and economic entomologists. In this work, the morphology of the jaws of the yellow grasshopper has been more thoroughly checked than those of any other acridian species. Many permanent and temporary mounts, as well as mounts of mandibles of all the several instars, were repeatedly checked.

The incisor lobes of *M. differentialis* are typically forbivorous. In an anterior-ventral view (fig. 3, LA) the four dentes of the left incisor lobe are as individually marked as are the dentes of *B. magna* (fig. 1, LA). The right incisor lobe is also similar in make-up to the typical forbivorous pattern. On the other hand, the denticles of the molar

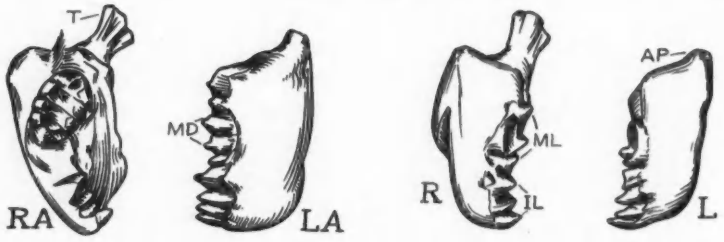

FIGURE 3. Herbivorous mandibles of *Melanoplus differentialis* (Thos.) (RA and LA), and florivorous-forbivorous mandibles of *Amblycorypha parvipennis* Stål (R and L).

RA, right mandible, mesial view, and LA, left mandible, anterior-ventral view, of *differentialis*. R and L, anterior-ventral-mesial views of right (R) and left (L) mandibles of *parvipennis*. These views are secured by turning the mesial margins of mandibles from the straight front anterior-ventral position slightly outward. AP, anterior articular process; IL, incisor lobes; MD, molar dentes; ML, molar lobes; T, tendon.

lobes of *differentialis*, although mastodontic in appearance, are arranged in a ridge-furrow pattern and approach an intermediate condition between the forbivorous and graminivorous models. The herbivorous acridian mandible pattern is based on this combination model as found in *differentialis* and is characteristic of the mixed feeders among the Cyrtacanthacrinae and Oedipodinae. Another morphological feature which characterized the Melanopli and the forbivorous Oedipodinae is found in the two large marginal molar dentes (MD) as shown in *differentialis* (fig. 3, LA) when compared with the single prominent marginal molar dens of *B. magna*.

The variations in the molar patterns of *M. differentialis*, however, are definitely marked. These variations range from a near approach to the mastodontic irregular arrangement of the molar dentes forming the grinding surfaces of conservative forbs feeders to the regular roughened

furrows and ridges not unlike the molar surfaces of certain graminivorous species.

To test further the food requirements of *M. differentialis* a series of cages was started May 19, 1941, stocked with specimens of first and second instar juveniles collected in the field. One set of caged hoppers was fed on a diet made up wholly of mixed grasses and another set on a diet wholly of mixed forbs.

The chief grasses supplied were *Andropogon saccharoides* Swartz and *Sporobolus heterolepis* A. Gray, the most abundant native prairie grasses. From the exotic group *Sorgum halepense* (L.) Pers. (Johnson grass) and *Cynodon dactylon* (L.) Pers. (Bermuda grass) were regularly provided. Among the crop plants only *Zea mays* L. was supplied. In addition several weed grasses were fed from time to time, but these were not always checked for species. Usually mature grass leaves were used such as were eagerly eaten by graminivorous acridians in other cages on the insectary shelves. Among the chief broad-leaved plants in the forbs cages were shoots of *Helianthus annuus* (L.), *Ambrosia aptera* (DC.), *Lactuca virose* (L.), *Gaillardia pulchella* (Four.), and *Parthenium hysterophorus* (L.). Representatives of the first three weeds in the above list in pure or mixed patches and Johnson grass are the most frequent indicators of thriving colonies of *M. differentialis* in north-central Texas.

The first adult appeared in one of the forbs cages on June 28. On July 7, there were ten adults and two last instars in this cage. In the grass cages, the first adult appeared July 9, and on July 17 there were ten adults in a total of twenty-two specimens. The individuals in the forbs cages completed their transformation and became adult on an average of twelve days eaelier than the individuals raised in the grass cages. The forbs cage specimens were definitely larger and appeared more vigorous than the individuals in the grass cages.

MANDIBLES AND FOODS OF OTHER ACRIDIDAE

In addition to the more detailed account of the mandibular morphology of the three species described above, the correlations between mandible structure and plant structure of eighty-six other species of the Acrididae are here briefly outlined and summarized. On the basis of fundamental similarity of mandible patterns these species belong to the subfamilies Acridinae (slant-faced grasshoppers), Oedipodinae (band-winged grasshoppers), Romaleinae (lubber grasshoppers), and Cyrtacanthacrinae (spine-breasted grasshoppers).

The species studied were usually those which were available for cage testing. They belong chiefly to the acridian fauna of north-central Texas; however, several species are from other areas of Texas and Colorado. As already stated in making his correlation analysis, the writer has used the critical cage studies of food preferences made by other investigators in addition to his own. The field activities of all the species here considered have been personally observed by the writer, and in most instances have been studied under field conditions for several years. Field records are of value chiefly to corroborate the host plant preferences of acridian species indicated in cages and as clues to other plants which may serve as food. It must be admitted that field evidence of food choices by grasshoppers is very illusive and easily misinterpreted.

From the viewpoint of phylogeny it is found that the majority of the species of a given genus or even subfamily have similar food preferences and hence have a general similarity in mandible patterns. However, if a species has changed in its food choices from the diet requirements of the majority of species in its subfamily or genus, the morphology of both mandible lobes (incisor and molar) has become adapted to the varying toughness of the plant tissues making up its diet. These mandible adaptations and phylogenetic divergencies are clearly shown in representative species of the Acridinae.

Acridinae

In this subfamily only three species of the twenty-four Acridinae studied have forbivorous mandible patterns. These three forbs feeders are *Acrolophitus variegatus* (Thos.), Isely, 1938, p. 569; *A. hirtipes* (Say), Criddle, 1933, p. 478; and *Bootettix argentatus* Bruner. The third is a Trans-Pecos, Texas, species and is always found in the field to be closely associated with *Larrea tridentata* (DC) Coville. In the writer's cages (1939), *B. argentatus* fed exclusively on the leaves of *Larrea*.

Graminivorous Mandibles.—With the exception of the three species noted above, all other Acridinae here reported have graminivorous mandibles. Several of these species have more highly specialized mandibles than those of *Mermiria maculipennis*. This specialization is expressed in the fusion of the dentes of the cutting edges of the incisor lobes and in shallow furrows and flattened ridges in the molar areas. As a result these species are adapted to use as their standard diet the compact abrasive tissues of the leaves of mature grasses.

The following Acridinae have graminivorous mandibles: *Mermiria texana* Bruner, *M. neomexicana* (Thos.), *M. maculipennis* Bruner, *M. m. macclungi* Rehn, *Achurum sumichrasti* Sauss., *Tryxalis brevicornis* (L.), *Mesochloa abortiva* Bruner, *Syrbula admirabilis* Uhler, *Opeia obscura* (Thos.), *Amphitornus coloradus* (Thos.), *Amblytropida occidentalis* (Sauss.), *Phlibostroma quadrimaculatum* (Thos.), *Orphulella pelidna* (Burm.), *O. speciosa* (Scud.), *Dichromorpha viridis* (Scud.), *Ageneotettix deorum* (Scud.), *Psoloessa texana* (Scud.), *Boopedon nubilum* (Say), *B. maculatum* Caudell, *B. auriventris* McNeill, and *Aulocara elliotti* (Thos.).

As far as the writer's cage evidence gives information, only one of the above species, *Ageneotettix deorum* (Isely, 1938a, p. 581–2) indicated that under starvation pressure it would turn to forbs for food. This appears to be in line with field evidence cited by Allred (1941) for *A. deorum* and *Aulocara elliotti* where these species are credited with the destruction of sagebrush, *Artemisia tridentata*. However, in Pfadt's cages (unpublished records) these range grasshoppers soon died when supplied only with fresh alfalfa.

Oedipodinae

The oedipodines have a wide range of food preferences and are a heterogenous subfamily in their diet requirements. Here are found (1) obligatory, graminivorous species, (2) oligophagous, forbs feeders, and (3) mixed feeders. The mandible patterns of the band-winged grasshoppers are as variable as are their food choices. A number of

species in this subfamily have been cage tested by the writer, and experimentally checked for food choices by Criddle (1933), et al.

The species of the Oedipodinae, as were the Acridinae, are grouped below on the similarity of mandible models. This grouping is found to parallel feeding behavior.

Grass-Feeder Mandible Patterns.—Arphia xanthoptera (Burm.), *A. simplex* Scud., *Chortophaga viridifasciata* (DeGeer), *Encoptolophus subgracilis* Caudell, *E. sordidus costalis* (Scud.), *Hippiscus rugosus* (Scud.), *Pardalophora saussurei* (Scud.), *Dissosteira longipennis* (Thos.), *Trachyrhachis kiowa fuscifrons* (Stål).

Forbs-Feeder Patterns.— Xanthippus corallipes leprosus Sauss., *Craty-pedes neglectus* (Thos.), *Tropidolophus formosus* (Say), *Spharagemon bolli* Scud., *S. equale* (Say), *Trimerotropis pistrinaria* Sauss., *Hadrotettix trifasciatus* (Say).

Mixed-Feeder Patterns.—Arphia conspersa Scud., *A. pseudonietana* (Thos.), *Camnulla pellucida* Scud., *Xanthippus corallipes pantherinus* (Scud.), *Leprus cyaneus* Cockerell, *Dissosteira carolina* (L.), *Spharagemon collare cristatum* (Scud.), *Trimerotropis citrina* Scud.

In the mixed-feeder group among the oedipodines, grasses are found to be the preferred diet and the mandibular structure, while intermediate, is clearly nearer the patterns of the graminivorous species. The depredatory warrior grasshopper, *Camnulla pellucida*, which has been studied by Parker (1930), Criddle (1933), and other economic entomologists, is primarily a grass feeder and notably destructive of cereal crops in the northern United States and Canada. *C. pellucida*, however, will also damage other field crops. *Dissosteira longipennis*, a range grasshopper and grass feeder, has been known to destroy beets and Irish potatoes (*in litt.*, Sam C. McCampbell, Extension Entomologist, Fort Collins, Colorado, October 20, 1941). Yet its mandible pattern is strictly graminivorous. One of the most puzzling species is *Xanthippus corallipes pantherinus*. The mandible pattern of the incisor lobes alone places it with the mixed feeders. The molar surfaces, however, are nearer the graminivorous group, although the furrows and ridges are rough. This species was thoroughly tested (1938a), and rechecked for the present work. In my cages, (summer, 1941) *X. c. pantherinus* lived for a considerable period roosting and nibbling at times on a wide assortment of forbs, but finally starved when grasses were absent from the vegetation provided in the cages.

Romaleinae

In a recent comparative study of the subfamilies of the Acrididae, based primarily on their phallic structures, Roberts (1941) has formed the new subfamily Romaleinae. In this subfamily are brought together several North American species which were formerly placed by various authors in the subfamilies Oedipodinae, Batrachotetriginae, or Cyrtacanthacrinae. The mandibles of the following species of the Romaleinae were examined: *Phrynotettix tschevavensis* (Haldeman), *P. robustus* (Bruner), *Taeniopoda eques* (Burm.), and *Brachystola magna* (Girard).

In mandibular morphology all of these are forbivorous since their jaw patterns are similar to those of *B. magna* described above. In Texas the first three of these species are found only in the Trans-Pecos.

Although the mandibles are highly adaptive, a fundamental subfamily pattern has been observed for a large majority of the species which belong to a given grasshopper subfamily. The mandibular structural parallelism of these species of Romaleinae which were variously classified by previous authors would appear to accord with Robert's revision which is based on a stable acridian character.

Cyrtacanthacrinae

The spine-breasted grasshoppers subsist for the most part on the leaves of forbs. A few species feed chiefly on the leaves of shrubs and trees. The mixed feeders which in this group are forbs-grass feeders will eat grasses when forbs are not available. Economic species, which are usually mixed feeders, will attack alfalfa, other legumes, cotton, corn, small grain, garden crops, and trees, apparently more or less indiscriminately. This polyphagous feeding behavior, which is characteristic of less than twenty-five per cent of cage tested grasshoppers, has been assumed by most entomologists to apply to all grasshoppers.

The chief mandibular differences between mixed feeders and forbs feeders among the melanopli, schistocercas, and other spine-breasted acridians are especially in the structure of the molar lobes. Among the strictly forbivorous species the dentes of the molar areas are pointed, appear to be irregular in position, and are here designated as mastodontic, whereas among the mixed feeders the dentes of the molar areas usually become more regular in form and frequently assume the ridge-furrow pattern; the incisor dentes, however, tend definitely toward the regular forbs model with distinct pointed dentes. The ridges are higher and the furrows deeper among the mixed feeders (fig. 3, RA) than are the ridge-furrow patterns of the strictly graminivorous species.

Forbivorous Mandibles.—The following Cyrtacanthacrinae have jaws adapted to feeding on forbs: *Schistocerca damnifica* (Sauss.), *S. lineata* Scud., *S. shoshone* (Thos.), *Hypochlora alba* (Dodge), *Paraidemona punctata* (Stål), *Campylacantha olivacea* Scud., *Aeoloplus t. bruneri* Caudell, *Hesperotettix viridis* (Thos.), *H. viridis pratensis* (Scud.), *H. speciosa* (Scud.), *Melanoplus texanus* (Scud.), *M. discolor* (Scud.), *M. flabellatus* Scud., *M. glaucipes* (Scud.), *M. ponderosus* Scud., *M. ponderosus eumera* Hebard, *M. femur-rubrum* (DeGeer), *M. keeleri* (Thos.), *M. packardii* Scud., *M. flavidus elongatus* Scud., *M. impiger* Scud., *Paroxya atlantica* Scud., and *Dactylotum pictum* (Thos.).

The above grouping of the Cyrtacanthacrinae is on the basis of their jaw morphology. Certain pest species listed above as *femur-rubrum* and *packardii* are reported by economic entomologists to destroy wheat and corn. It is a safe forecast, however, that if these economic species, as well as the mixed feeder group which follow and are here designated as forbs-grass feeders, were experimentally tested to discover their optimum subsistence and reproductivity diets, they also (with the possible exception of *M. mexicanus*) would require foods consisting of selected forbs.

Mixed Feeder Mandibles.—*Schistocerca americana* (Drury), *S. obscura* (Fab.), *S. alutacea* (Harris), *S. vaga* (Scud.), *Melanoplus scudderi latus* Morse, *M. differentialis* (Thos.), *M. bivittatus* Say, *M. confusus* Scud., *M. mexicanus* (Sauss.), *Phoetaliotes nebrascensis* (Thos.).

Four species of the schistocercas were first cage tested for food choices during October 1941. All of these bird grasshoppers indicated that the leaves of trees and shrubs were high on their list of preferred foods. The choice of these ligneous foods is reflected in their mandible morphology, and in the main the forbivorous pattern is followed. *Schistocerca damnifica* and *S. alutacea* definitely selected the leaves of the oaks, *Quercus stellata* Wang (post oak) and *Q. marilandica* Muench (blackjack oak). These two grasshopper species are separated in the above grouping on the basis of jaw structure, although the food preference data thus far obtained would place them together. *S. obscura* and *S. americana* were less specific in their food choices, accepting herbaceous leaves and under pressure fed to a limited extent on grasses. Jones (1939, p. 326) reports *S. americana* as defoliating young apple trees in southwestern Missouri.

Dr. J. R. Parker has recently called the writer's attention to a paper by Howard (1894) on "Damage by the American Locust." Dr. Howard quotes a report on field observations by D. W. Coquillett who discusses with critical detail the differential feeding of great swarms of *Schistocerca americana* in Roanoke County, Virginia, during August 1894. Coquillett points out that certain kinds of trees were stripped of all of their foliage while the leaves of other species of trees were untouched by the locusts. He noticed that low succulent vegetation was not eaten while mature leaves of certain plants were consumed. These field observations by Coquillett tally well with the feeding behavior of *Schistocerca americana* as observed in my cages in the fall of 1941.

Graminivorous Mandibles.—Only four species of Cyrtacanthacrinae were found to be near to the graminivorous mandible patterns: *Leptysma marginicollis* Serv., *Paropomala wyomingensis* (Thos.), *Melanoplus infantilis* Scud., and *M. plebejus* Stål).

Marginicollis is a widely distributed lake and stream acridian and is called the cattail grasshoper by Ball (1936); *wyomingensis* is a plains species; *infantilis* is from Colorado; only *plebejus* belongs to the prairie acridian fauna.

As a group the Cyrtacanthacrinae are, by preference, forbs eaters. As a result the forbivorous model is the chief jaw pattern of the spine-breasted grasshoppers. Many of the Cyrtacanthacrinae are wholly forbivorous and starve or are unable to produce eggs if maintained on a grass diet. My cage investigations concerning food choices of twenty-two species of Texas Cyrtacanthacrinae show that only one, *Melanoplus plebejus*, indicated a definite food preference for grasses. Under starvation pressure *M. plebejus* will for a time subsist on forbs. Criddle (1933) in his experiments with the feeding behavior of Canadian spine-breasted acridians reports five graminivorous, fourteen forbivorous, and fifteen mixed feeder species. Eight of Criddle's fifteen mixed feeders have also been cage tested for food choices by the writer. All of these and probably most of the other seven Canadian species are actually forbs-grass feeders. Pfadt (summer 1940) found alfalfa as one of the first choice foods for eight species of Wyoming grasshoppers, all Cyrtacanthacrinae. Fritz (summer 1940) experimenting with large numbers of *Aeolophus t. bruneri* Caudell found that for maximum longevity and reproductivity this spine-breasted grasshopper required a diet of shoots

of the Russian thistle. This need of forbs in the diet of the Cyrtacanthacrinae for maintenance and fecundity would, judged by current literature, appear to be unusual, but further food preference tests will probably show that many species of the Acrididae the world over are dependent even to the extent of species survival on forbs for food.

Uvarov (1928) in his thorough summary and review of world "Locust and Grasshopper" literature quotes numerous authorities which call attention to selective feeding of even pest grasshoppers. On the basis of these citations, however, as well as his extensive first-hand knowledge of locusts and Orthoptera in general, Uvarov concludes that grasshoppers are primarily "graminaceous." In speaking of the Italian grasshopper, *Calliptamus*, Uvarov (1928, p. 286) states: "The feeding habits of *Calliptamus* are peculiar." After calling attention to the forbivorous feeding behavior of this grasshopper, he says: "This constitutes a sharp distinction between *Calliptamus* and the majority of the Acrididae, in which Graminae are the staple food."

On the contrary it should be noted that recent grasshopper food preference experiments cited above show that fully half of the acridians which were cage tested (Criddle, Isely, and Pfadt) require a diet of forbs for their normal, healthful maintenance, longevity, and reproductivity.

MANDIBLE PATTERNS OF THE TETTIGONIIDAE

The mandibular models of the several species of the Tettigoniidae examined are found as a rule to have a standard subfamily pattern in the structure of their incisor and molar lobes. The morphology of these mandibles is uniformly correlated with the food specificity of the species concerned. Although the number of species involved is much smaller, cage tests show that the Tettigoniidae have a wider range of food preferences than do the Acrididae. Hence, as would be expected, we find greater basic variations in jaw structure.

The mandibles of the katydids are similar in fundamental pattern to those of the forbivorous Acrididae. The mandibles of the predaceous and seed-eating Tettigoniidae, however, are quite different from any acridian models studied and these mandibles are adapted to foods only rarely used by the Acrididae.

The subfamilies considered are the Phaneropterinae, Pseudophyllinae, Corpiphorinae, Conocephalinae, and Decticinae. The mandibular morphology of representative species for each subfamily is briefly described.

Phaneropterinae and **Pseudophyllinae**

Florivorous-forbivorous Mandibles.—The mandibular morphology of *Ambylcorypha parvipennis* Stål may be taken as representative of the flower-forbs feeders. In the anterior-ventral view of the partly spread incisor lobes of *A. parvipennis*, three dentes are seen, left and right, instead of four as in the forbivorous Acrididae (fig. 3, R and L). The individual incisor dentes are well separated, distinctive, and pointed. The molar lobes, while somewhat mastodontic, are proportionally much smaller in area than are the molar surfaces of acridians of similar size. These characteristics are shown in fig. 3. *A. parvipennis* was grown

from eggs to adult in cages during the spring and summer of 1941. This species proved quite hardy and easy to rear. The young tender leaves of several species of the Onograceae were especially acceptable as food although the buds and young leaves of several other forbs were eaten. Flowers were greedily eaten. Grasses in general were on the refused list. Cage studies and food habits of five other species of breeding phaneropterines (Isely, 1941a) appeared to emphasize the need of plant shoots in flower for optimum reproductivity. The fact that pollen grains are frequently abundant in the dissected crops of the katydids which were taken in the field emphasizes their fondness for a diet of flower parts. On account of the definite bud-flower relations of the phaneropterines which were studied in cages, their light mandibles are here designated as the flower-forbs mandibles.

In addition to the five species of Phaneropterinae previously cage tested for food preferences, two other species, *Scudderia furcata* and *S. texensis*, were checked during September and October, 1941, to discover their feeding behavior. It was found that these late summer bush katykids also have a marked fondness for flower parts although the leaves of woody shrubs, in addition to the leaves of herbs, were also on their menus. Riley (1874, p. 166) names oak-leaves as the preferred diet of *S. furcata*. (Listed as *Phaneroptera curvicauda* (DeGeer) by Riley, but as Blatchley indicates, the species he tested experimentally was *S. furcata*.) In general the jaws of the Phaneropterinae examined average proportionally smaller than the mandibles of the short-horned grasshoppers. While each species has individually distinctive jaw features, the flower-forbs mandibles are found to be characteristic of the following Phaneropterinae:

Dichopetala emarginata Bruner, *Arethaea constricta* Bruner, *A. ambulator* Hebard, *A. grallator* (Scud.), *Amblycorypha huasteca* (Sauss.), *A. parvipennis* (Stål), *A. uhleri* (Stål), *A. oblongifolia* (DeGeer), *Scudderia texensis* Sauss. and Pictet, and *S. furcata* Bruner.

Lignivorous Mandibles.—The Pseudophyllinae are represented by a single species in north-central Texas, *Pterophylla furcata laletica* Hebard. This subspecies was recently described by Hebard (1941). The same species was listed by the writer (1941a) as *Pterophylla camellifolia* (Fab.). The mandibles of this arboreal katydid are similar in their basic make-up to those of the flower-forbs model, but differ in certain features. The cutting edge of the left incisor lobe of *P. f. laletica* is made up of four distinct, sharp, pointed dentes instead of three. These features are easily observed in an anterior-ventral view of the left mandible. The molar areas of the mandibles are proportionally larger among these ligneous feeders. For the genus *Pterophylla*, Hebard (1941) records five species and subspecies, each occupying its own territory but covering essentially all of the deciduous forest areas of the eastern half of the United States where oaks are found. The sedentary habits of the *Pterophylla* are well known. Many individuals, doubtless, spend their entire life on the same tree where they were hatched. It is possible that colonies may be maintained from year to year on isolated large oak trees. This implies a monophagous feeding behavior. Cage tests would probably show that for optimum longevity and fecundity oak leaves are necessary to the maintenance of the various species of *Pterophylla*.

The jaw pattern of *Microcentrum rhombifolium* (Sauss.) is of special interest. While this species is placed in the subfamily Phaneropterinae, its mandible structure is more like that of *P. f. laletica*, one of the Pseudophyllinae. When one finds that *M. rhombifolium* is also an arboreal katydid feeding on the leaves of oaks and other trees (Riley, 1874, p. 158), we see again that food is the determining factor in explaining similarity in mandible patterns rather than actual or perhaps supposed taxonomic relationship.

Corpiphorinae, Conocephalinae, Decticinae

The species of these three subfamilies have mandibles which are different in morphology from those previously described. While individually distinctive, as far as the species examined are concerned, the mandibles of all the members of the three subfamilies have a similar fundamental jaw pattern. The dorso-ventral or the proximal-distal axes of the mandibles are definitely elongated (fig. 4) and the lateral

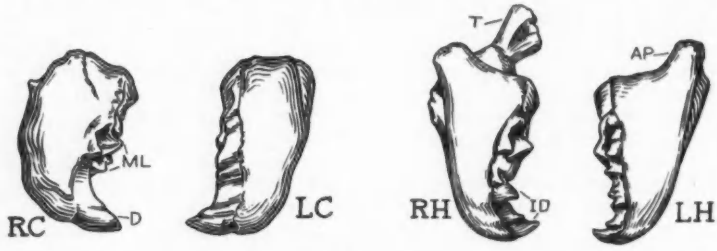

FIGURE 4. Seminivorous mandibles of *Neoconocephalus robustus crepitans* Scud. (RC and LC), and carnivorous mandibles of *Pediodectes haldemanii* Girard (RH and LH).

RC and LC, anterior-ventral views of mandibles of *crepitans*. The right mandible (RC) is turned out slightly so as to better show molar lobe. The incisor dentes are fused forming the single dens (D). RH and LH, anterior-ventral-mesial view of mandibles of *haldemanii*. The mandibles are turned out slightly from anterior view. AP, anterior articular process; ID, incisor dens; IL, incisor lobes; ML, molar lobes; T, tendon.

axes are proportionally narrower than the corresponding parts of the mandibles of the other Tettigoniidae and Acrididae heretofore considered. This greater dorso-ventral length is chiefly the result of a distal extension of the basal portion of the mandibles thus giving a handle, as it were, for reaching and grasping, especially by the apical incisors.

Seminivorous Mandibles.—The food preference tests of representative Corpiphorinae were not undertaken until the summer of 1941. Preliminary cage testing, described below, proved that the two available species, *Neoconocephalus robustus crepitans* Scud. and *N. tripos* L., were chiefly seed eaters and that they have distinctive mandibles.

In these species the distal incisor lobes are extended into a narrow chisel-shaped single dens, which results in an elongation of the dorso-ventral axes of both mandibles and reminds one of rodent incisor specialization. These incisor dentes overlap, left to right, ventrally.

The molar areas are tuberculose and not extensive. Such rodent-like incisor teeth would appear to be well suited to the shelling of seeds from the spikelets of grasses, (fig. 4, RC and LC).

In April, 1941, a few specimens of over-wintering *N. triops* were caged for behavior study. They refused to eat a wide assortment of vegetation provided as food and ultimately starved. On July 19, 1941, eleven specimens of a new generation of *N. triops* and fourteen individuals of *N. r. crepitans* were caged separately in a second attempt to discover the diet of these cone-heads. In their natural habitat they are always associated with tall grasses. Accordingly, their cages were supplied with a wide range of grasses and forbs from their optimum habitats. Since their vicious biting, when taken in the field, suggested that possibly these nocturnal long-horns were carnivorous, various insects were also placed in the cages. Among the insects were nemobid crickets, leafhoppers, flies, nymphs of acridians and meadow grasshoppers. A day by day count indicated that the insects offered as food were unmolested. There was some slight nibbling on stems and fruits pods of forbs. At night the neoconocephalans seemed to be hunting for food on the floor of the cages, but in the main, a hunger strike prevailed. Leaves of forbs, grasses, insects—all were unacceptable even as starvation rations. After three days' experimentation, almost by chance, seed-bearing shoots of green grasses were put into the bottles which held other fresh vegetation. Observation after dark showed at once that the hunger strike was over, as all individuals in both cages were eagerly feeding on the seeds in the spikelets of the grasses. Examination in the morning showed the grass seed-heads riddled. Among the grasses in fruit supplied were the following, which are listed in order of apparent preference: *Setaria viridis* (L) Beauv., foxtail; *Panicum helleri*, Nash, wild rice; *Paspalum dilatatum* Poir, Dallas grass; *Echinochloa colonum* (L) Pers.; *Sorgum halpense* (L.) Pers., Johnson grass. Forbs in the fruit were also supplied; among these were *Melalotus*, *Lepidum*, and *Gaillardia*. These were not eaten but the grasses were riddled. Johnson grass fruit heads seemed to be the least preferred among the grasses offered, although under present conditions in north-central Texas, this appears to be the most available and abundant food plant where optimum populations of these two species are located by night-time stridulatory evidence.

The diurnal behavior of these Corpiphorinae is of interest. Many nocturnal Tettigoniidae, when confined in cages, show considerable activity during the day, which varies with the species concerned. These cone-heads, however, were passive during the daytime and as a rule hung head down among the shoots of the vegetation in the cages; after dark their activity was resumed. In the field, active stridulation is usually delayed for about thirty minutes after dusk.

Carnivorous Mandibles.—Two species of the Decticinae, *Pediodectes haldemanii* Girard and *P. nigromarginatus* (Caudell), were rather extensively cage tested (Isely, 1941a) as to their feeding behavior and were found to be "wholly carnivorous."

The mandibles of *P. haldemanii* are selected as representative of the carnivorous jaw model (fig. 4, RH and LH). The dorso-ventral axes are definitely elongated; the grinding surfaces of the molar lobes are much

reduced. The three incisor dentes are somewhat fused and distally extended to form a cutting and grasping hook. The parallel with carnivorous mammal jaws is further emphasized as one studies the structure of the tiger-like biting mandibles of these Decticinae. In addition to *P. haldemanii*, the mandibles of four other species were examined, *Rehnia cerebrus* R and H, *Pediodectes nigromarginatus* (Caudell), *P. stevensonii* (Thos.), and *Anabras simplex* Haldeman.

All of these have typically carnivorous mandibles. Further cage testing would probably show that North American Decticinae are chiefly carnivorous rather than "primarily herbivorous" as suggested by Caudell (1907). Fabre found the European "White-faced Decticus" to be predaceous. Burr, Campbell, and Uvarov (1923) report several Macedonian Decticinae to be "fierce carnivora." The notorious Mormon cricket, *Anabras simplex* Haldeman, supplies a striking exception by its omnivorous feeding activities. No North American grasshopper has been more critically checked and observed in field and laboratory by economic entomologists. Swain (1940), after intensive field work, reports four hundred and sixty plant species which *Anabras* definitely attacks and damages. Cowan (1929) finds that *Anabras* is not only polyphagous but predaceous, cannibalistic, and especially adept at shelling all the grains found in seed heads of cereal crops. Its mandibles are similar to those of *Pediodectes haldemanii* though proportionally somewhat less elongated. However, only a small series was examined. In *Anabras*, then, we have a species which is seminivorous, carnivorous, forbivorous, and graminivorous. An indiscriminate taste and greed for all organic stuff appears to be the best explanation for the omnivorous feeding behavior of *A. simplex* and *Peranabras scabricollis* Thos., two Decticinae which are economic species of prime importance in the western United States.

The writer's observations of *Anabras* have been limited to a few weeks of field study in the area of the Rocky Mountain Biological Laboratory, Gothic, Colorado, (July-August, 1932). The brief review of its feeding behavior, summarized above, is based on the reports of several investigators of the Mormon cricket.

Carnivorous-seminivorous Mandibles.—Only a short time was given to cage investigations of the food preferences of the Conocephalinae (September-October, 1941). The following species of the Conocephalinae were checked for their feeding activities: *Orchelimum vulgare* Harris, *O. silvaticum* McNeill, *O. nigripes* Scud., *Conocephalus fasciatus* (DeGeer), and *C. strictus* (Scud.).

These observations indicate that the five species tested vary considerably in their feeding behavior. In cage experiments with these alert and timid grasshoppers, it was difficult to observe instances of the active capture of insects as was easily done in the case of the Decticinae. The other insects placed in Conocephaline cages were, however, consistently reduced in numbers and occasional observations were made of contact and capture between predator and prey. The shelling of grass seed heads and the eating of grass seeds showed a feeding behavior similar to that of the cone-heads. The feeding on the leaves of forbs and grasses was exceedingly meager. Starvation tests, which were only preliminary, appeared to indicate that the Conocephalinae would nibble on grasses

and grass stems under starvation pressure. Under these conditions they would live for a considerable period, but it was clearly indicated that although the leaves and stems of grasses were unpalatable, grass seeds were eaten with avidity. In view of this feeding behavior of the Conocephalinae, their mandibles are tentatively designated as carnivorous-seminivorous, though in all five species examined, the mandibles are essentially carnivorous in pattern. The mandibles of *O. vulgare* are figured by Yuasa (1920, pl. 4, figs. 79 and 82). Study of the feeding behavior and jaw structure of the various species of the Tettigoniidae reveals an entire absence of graminivorous mandibles and the almost complete refusal of the leaves of grasses for food.

DISCUSSION

Biological Implications.—The close correlation of the structure of mandibles and the food preferences of grasshoppers is a further confirmation of species adjustments to a wide ranging variation in available food. The striking parallelism shown in the morphology of the mandibles of grasshoppers and mammals, as a result of similar adaptations to varying plant tissues and animal food, is just another impressive exemplification of convergent evolution.

Further study of mandibular morphology, coupled with food testing, should contribute to an understanding of orthopteran ecology and help to evaluate the factors which play the important roles in terrestrial communities. From the viewpoint of ecology it is evident that all experimental data dealing with food specificity of grasshoppers thoroughly support the claim that grasshopper species are just as perfectly synchronized to the niches of their species activity and to their microhabitats as are organisms in general. The availability of specific host plants, contrary to the conclusions of Urquhart (1941, p. 79), looms large as one of the important environmental factors in evaluating conditions which will help explain the local and regional distribution of grasshoppers.

An understanding of mandibular morphology will afford economic entomologists clues which will enable them to forecast with more assurance the possible hazards to crops and range from shifting populations of waste land and desert grasshoppers.

The conviction that all of the hundreds of different species of grasshoppers eat everything green, and especially grass, is no longer tenable. These investigations show that many of the species which have been cage tested are more frequently beneficial than harmful because their host plants which they hold in check are competitors of range grasses.

Economic entomologists working on the problem of the control of pest species with highly potent baits (Shotwell, 1942) should also investigate the possibility of the eradication of primary host plants as a method of cutting down the longevity and fecundity of certain oligophagous pest species, *e. g.*, ***Melanoplus bivittatus*** and ***M. differentialis***. Food specificity experiments already under way (Pfadt and Fritz) should be vigorously prosecuted for all economic species.

The taxonomist and the evolutionist will find in structure and variations of mandibles an aid to orthopteran classification and to species differentiation and possibly some clues to speciation.

Grasshoppers and Vegetation.—Many acridians are irrevocably associated with the Gramineae for food, shelter, and sod or grass roots in which to deposit their eggs. Field and laboratory observations make it clear that most of the Acridinae have graminivorous mandibles and become adapted in body form and color to the stems or leaves of the grasses of their microhabitats. Feeding tests definitely indicate that for these graminivorous species, grass diets are necessary. Certain of the long-horns use grass leaves and spaces between the leaves as repositories for their eggs. Other tettigoniids appeared to relish and feed with avidity on grass seeds. Tettigoniidae tested in cages refused or only slightly nibbled the blades or stems of grasses, even under starvation pressure.

While certain acridians are wholly graminivorous, it is evident from field and experimental data that other grasshopper species, genera, and subfamilies are just as definitely associated with forbs. Here belong the Cyrtacanthacrinae, Phaneropterinae, and certain other non-graminaceous groups. Several forbivorous species are essentially monophagous. While not necessarily limited to a single host plant, a number of species belonging to the north-central Texas grasshopper fauna live very successfully and appear to secure all diet needs for their longevity and reproductivity while feeding on a single host plant. In the field these species are found in maximum populations either on or in close proximity to the plant species which cage tests have shown to be their host plant or first choice food plant in the area under observation. Many of these grasshoppers, whether monophagous or restricted oligophagous species, strikingly harmonize in body form and color with the host plant leaves or stems which serve as their backgrounds. These species not only feed on forbs but have forbivorous mandibles. Carnivorous tettigoniids are usually nocturnal and use plants chiefly for roosting and cover. The same plants may supply food and shelter for their insect prey.

Food Specificity Analyzed.—Food preference and maintenance diet experiments previously cited and discussed in this paper point to but one conclusion; grasshoppers, in common with all organisms from bacteria to man whose diet requirements have been critically tested, demand for health, longevity, and reproductivity, an adequately balanced diet.

Food specificity for insects in general, is well established. Only four representative researches will be cited here: Glaser (1923), D. Isely (1928), Brues (1940), and Painter (1941). The idea of food specificity in grasshoppers was experimentally demonstrated by Riley (1874) seventy years ago. Even economic acridians, which destroy nearly all crops, need specific foods (Hodge, 1933, and Sanderson, 1939).

All of the North American Acrididae are phytophagous. In cages many species will eat the dead bodies of other acridians even when supplied with their preferred plant food. No short-horned grasshopper, however, even under starvation pressure has shown any predatory tendencies in the writer's cages beyond the eating of antennae of weaker neighbors.

Mandible Patterns.—Four chief mandible models are shown by southwestern and western United States grasshoppers (Acrididae and

Tettigoniidae) which adapt the different groups, chiefly subfamilies, for wide-ranging diet possibilities. Besides the four major models, four combination models have been evolved, making a total of eight.

Representative species have been discussed which exemplify the basic and combination models as follows: (1) forbivorous mandibles are found largely among the Cyrtacanthacrinae, Romaleinae, many Oedipodinae, and a very few Acridinae; (2) graminivorous models are characteristic of the Acridinae, many Oedipodinae, and a very few Cyrtacanthacrinae; (3) carnivorous jaws are shown by the Decticinae; (4) seminivorous mandibles are most clearly seen in the special pattern of the seed-eating Corpiphorinae.

The combination patterns are less easily defined but show interesting variations: (5) herbivorous mandibles belong to the mixed feeders, especially the notorious pest grasshoppers ***Camnulla pellucida*** (Oedipodinae), ***Melanoplus mexicanus*** (Cyrtacanthacrinae), ***et al.***; (6) florivorous-forbivorous mandibles include most of the Phaneropterinae; (7) lignivorous jaws seem to have reached only generic group differentiation and are represented by ***Pterophylla*** and ***Microcentrum*** (Tettigoniidae) and by several ***Schistocerca*** (Acrididae) which may be included here rather than in the forbivorous grouping above; (8) seminivorous-carnivorous species, represented by the Conocephalinae, are here separated from other Tettigoniidae on account of their feeding behavior and no distinctive jaw pattern has been determined. Their mandibles are essentially carnivorous, but feeding activities suggest that further study may justify their separation from the more strictly carnivorous decticids. The omnivorous feeding behavior of ***Anabras simplex*** would appear to demand a separate group, but here, as in (8), the pattern is carnivorous.

The above groupings represent only a small segment of the world-wide order Orthoptera and it should be evident that these groupings must be viewed as tentative and provisional. Since grasshopper mandible patterns, however, follow lines of specialization characteristic of the chewing mechanisms of all kinds of animals the biological soundness for these mandible models as here characterized would appear to be substantiated.

The mandibular patterns of these southwestern United States grasshoppers will doubtless be found to be representative of many species of the Acrididae and Tettigoniidae in all parts of the world.

SUMMARY

1. Of 89 Acrididae examined, 34 had graminivorous, 37 forbivorous, and 18 herbivorous mandibles.

2. Among the 24 Tettigoniidae studied, 10 had florivorous-forbivorous, 2 lignivorous, 2 seminivorous, 5 carnivorous, and 5 seminivorous-carnivorous mandibles.

3. Morphologically, mandibles are definitely correlated with food, but in the main, mandible patterns follow genetic lines. Strangely enough, certain of the species which have broken away from usual subfamily feeding behavior are also quite dissimilar in structure from typical subfamily representatives as characterized by taxonomists, *e. g.*, ***Acrolophitus variegatus*** (Acridinae), ***Leptisma marginicollis*** (Cyrtacanthacrinae), ***et al.***

4. Variations in mandible structure within a species are especially marked among the mixed feeders.

5. Food specificity appears to offer tangible clues toward a better understanding of grasshopper communities and the interrelationships between these Orthoptera and plants.

6. It should be evident that food specificity research will contribute to further progress in working out the control of pest hoppers.

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A NEW SPECIES OF PLUMMERELLA (HOMOPTERA, CICADELLIDAE) FROM MEXICO

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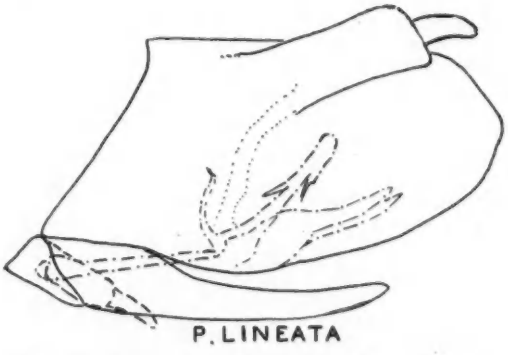
The genus *Plummerella* was recently described by the writer (Ann. Ent. Soc. Amer., 35: 200, 1942) to include a species *alpina* which has been found only at high altitudes in the mountains near Mexico City. Another species not available for study at the time *alpina* was described is being described at this time from specimens collected at a lower altitude, some 200 miles west of Mexico City. *P. alpina* occurs in the tall clumps of bunch grasses which are common in the pine and fir forests at some 10,000 feet elevation. *P. lineata* occurs on the tall grasses growing in the oak-pine forests at an elevation of some 7500 feet. They are closely related but may be distinguished by their coloration, shape and by the male genital structures.



P. lineata, lateral view of male genital structures.

Plummerella lineata n. sp.

In form and general appearance resembling *alpina* but more narrow and elongate, different in color and with different male genitalia. Length, male, 7 mm.

Vertex elongate, convex on dorsal surface, one and one-half times as long as basal width between eyes. Ocelli about one-fifth the distance from base to apex which is bluntly pointed.

Color.—Pale yellow with dark markings. Vertex with a pair of median, proximal parallel lines arising at apex and extending almost to base. Each line is broadened not far from apex and gives rise on the outer margin to an oblique line which extends almost half-way to base and is parallel to the outer margin. Just anterior to the ocelli,

a short oblique spur arises on the outer margin of each parallel line. Pronotum with the lateral margins dark brown and four prominent brown marks on median anterior half. Scutellum with three short longitudinal parallel brown lines on anterior half, the median line terminating in a transverse brown dash on middle. Elytra rather bright yellow, a broad brown longitudinal stripe just above costa and parallel to it. Pale brownish diagonal stripes are on the clavus and the inner apical margin is brownish subhyaline.

Genitalia.—Male plates narrow, elongate, triangular, the apices rolled and divergent. Pygofer more than one-third longer than plates. Styles slightly more than one-third as long as plates, rather narrow, the apical half deeply concavely excavated on outer margin forming a long curved, finger-like process with a pointed apex. Aedeagus composed of several parts as in *alpina*. The anterior process extends erect from the base. Caudad to this is a rounded, elongate process, extending dorso-caudally and with a ring of spines extending basally just beyond a constriction at about its middle. The posterior-basal structure is cleft on posterior half, forming a pair of narrowed apical pieces which are attached to a broader basal portion.

Holotype male and paratype male collected from tall grass in the oak forest association at Carapan, Mich., Mexico, 7500 feet elevation, October 2, 1941, (Km. 432) by C. C. Plummer, J. S. Caldwell, E. E. Good and the author.

TYROGLYPHID MITES IN STORED PRODUCTS. I. A SURVEY OF PUBLISHED INFORMATION, by M. E. Solomon. Pages iv+36, 5 figures, 6 x 9½ inches, paper bound. Published by His Majesty's Stationery Office, London. Price, 9d.

The broad scope of this paper is indicated by the table of contents: 1, Introduction; 2, Systematics; 3, Morphology and Internal Anatomy; 4, Biology (life history, nutrition, and behavior); 5, Bio-ecology (occurrence, means of distribution, parasitism, medical and veterinary significance, and natural enemies); 6, Physical Ecology (effects of temperature and humidity); 7, Tyroglyphids in Stored Products, and their Control (pp. 13-22); 8, Discussion; 9, References (pp. 25-36).

The information presented in this paper has been accumulated during three years of work on tyroglyphid mites. This work is a part of the research program of the Department of Scientific and Industrial Research on the infestation of stored products by insects and allied pests. The tyroglyphid mites are of common occurrence in stored products, where they may cause considerable damage. The literature on these mites, while extensive, is scattered, and this paper presents a summary of the published information which will serve as a guide for use by those concerned with the study and control of these pests.

In his "Discussion" the author draws three principal conclusions: (1) Moisture plays the dominant role in the ecology of the tyroglyphids, and therefore the provision of sound, dry storage conditions is of first importance. (2) There is a need for quantitative data on the rate of increase and the direct and indirect damage done under various storage conditions, the physical aspects of which should be dealt with quantitatively. (3) More critical work on control measures is needed, with attention given to the special resistance of the hypopus and egg stages.—D. J. B.

ENVIRONMENTAL CONTAMINATION BY AN INSECT PARASITE AND THE EFFECT ON HOST SELECTION[1]

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One of the most interesting factors affecting host selection, or host suitability (which term is used depends upon the viewpoint), is that of host "conditioning," as reported by Salt (1937) for *Trichogramma*. *Trichogramma* females so contaminate eggs of their host, *Sitotroga*, by walking over them, that the eggs may not be acceptable to other females. This phenomenon is apparently caused by a water-soluble substance secreted by certain tarsal glands of the females examining or walking over the host eggs.

The present paper deals with a somewhat similar phenomenon, discovered during investigations with populations of the housefly, *Musca domestica* L., and its pupal parasite, *Mormoniella vitripennis* (Walker). This phenomenon, however, concerns contamination of the experimental environment, or habitat, so that a normal host, even though found, may not be successfully parasitized.

The experimental environment of the present tests was similar to that described in detail in an earlier paper (De Bach and Smith, 1941, p. 365). Ten-gallon tins having tight, insect-proof lids and containing either 2 or 6 quarts of barley were used. Puparia of the host (*Musca domestica*) were distributed through the grain, through which the parasites (*Mormoniella vitripennis*) crawled in search of their hosts.

In the course of the necessary preliminary work with the experimental universe that was developed during the population studies mentioned above (De Bach and Smith, 1941), a change in per cent parasitization took place so gradually that it was not noticed until parasitization dropped to a very low point. When the drop in parasitization was first noticed, difficulty in searching for hosts was thought to be the cause. In August, 1939, the number of hosts used in experimental tests was therefore doubled, to lessen the supposed difficulty in searching. Despite this advantage in favor of increased parasitization, a large part of these tests showed no parasitism whatever. A fair number of the hosts had been "stung,"[2] but practically no eggs had been deposited by the parasites.

These puzzling results led to a compilation of the experimental data for several preceding months; this revealed that there had been a steady decline in amount of parasitization in tests thought to be exact replications. (See Table I.) Even after the host density was doubled and the amount of barley was reduced, from 6 quarts to 2 quarts, later

[1]Paper No. 504, University of California Citrus Experiment Station, Riverside, California.

[2]Hosts that have been "stung" have been killed by the insertion of the parasite's ovipositor, either in feeding or egg-laying.

in August, parasitism remained practically nil (Table II). Tests were immediately begun to determine the cause of the decline.

Various miscellaneous trials were unsuccessful. Then recollection of Salt's (1937) report on host-conditioning in the case of *Trichogramma*, previously mentioned, led to the thought that perhaps the housefly

TABLE I

DECLINE IN PERCENTAGE OF PARASITIZATION OVER A FOUR-MONTH PERIOD IN 1939, IN TESTS IN WHICH PARASITES (*Mormoniella vitripennis*) SEARCHED FOR THE PUPARIA OF THEIR HOST (*Musca domestica*) THROUGH 6 QUARTS OF BARLEY GRADUALLY CONTAMINATED BY REPEATED USE.*

	Experimental Tests					Control Tests (No Barley)
Date	Number of Replications	Total Number of Parasites	Total Number of Hosts	Hosts Parasitized		Per Cent Parasitization
				Number	Per Cent	
May.....	6	180	180	44	24.4	61.7
June.....	18	540	540	41	7.6	63.0
July.....	8	240	240	13	5.4	52.5
August...	12	380	760	7	0.9	51.7

*Except in August, when the host density was increased, 30 parasites and 30 housefly puparia were used in all tests.

TABLE II

THE EFFECT OF CONTAMINATED BARLEY* ON PARASITIZATION, IN TESTS IN WHICH 40 PARASITES SEARCHED THROUGH 2 QUARTS OF GRAIN FOR 80 HOST PUPARIA.

Test	Total Number of Hosts Stung	Total Number of Hosts Parasitized	Percentage of Hosts Parasitized
1.....	33	0	0.00
2.....	50	1	1.25
Control (no barley)....	62	37	46.25

*The barley has been used repeatedly in previous tests and was used in these tests without cleaning.

parasites were in some way contaminating the barley by running over it in the course of their search for their host, so that, after a time, oviposition was inhibited. There was also a possibility that the condition might be due to continued contact of the puparia with the barley, or to the fact that the experimental tins had not been cleaned after use in preceding tests. Experiments were designed to test these hypotheses.

In these experiments 40 *Mormoniella* searched for 80 puparia through 2 quarts of barley, either new, washed in water, or contaminated by use in previous experiments. The tins were either clean or contaminated (previously used). The results of the experiments, presented in Table III, show clearly that contaminated barley is the sole factor affecting parasitization, and that contaminated barley which has been washed in water and dried is just as good as new grain for experimental purposes. For experiments 1 to 5, inclusive, chi square is 39.6, showing a high probability that these experiments *are not* homogeneous; for experiments 1 to 4, inclusive, chi square is 1.25, showing a high probability that these experiments *are* homogeneous. We may therefore assume that the two types of tins and two types of grain in experiments 1 to 4 show no significant differences, and that the difference in per cent parasitization between the groups 1 to 4, inclusive, and number 5 is due solely to contaminated barley.

TABLE III

EFFECT OF CLEAN OR CONTAMINATED (PREVIOUSLY USED) BARLEY AND CONTAINER ON PARASITIZATION, IN TESTS IN WHICH 40 PARASITES SEARCHED THROUGH 2 QUARTS OF GRAIN FOR 80 HOST PUPARIA.

Test	Experimental Setup	Number of Hosts Parasitized	Percentage of Hosts Parasitized
1	New barley in clean tin	26	32.50
2	New barley in contaminated tin	31	38.75
3*	Washed† barley in clean tin	26	34.66
4	Washed† barley in contaminated tin	32	40.00
5	Contaminated barley in contaminated tin	1	1.25

*In this test only 75 host puparia were used.
†Washed in water.

Observations indicate that barley is contaminated when numerous parasites have run over the grain. This conditioning could, however, be due to the fact that many puparia have been mixed with the grain, with the result that the host-odor stimulus is so great as to cause females to be unable to distinguish readily between barley grains and true hosts, and therefore to cause them to attempt oviposition in the barley grains.

A phenomenon of this sort has been discussed by Ullyett (1936, p. 260–261) in his analysis of Salt's (1935) work with *Trichogramma*, on host selection. *Trichogramma*, according to Salt, selected particles of sand when host eggs were equally available, because the females preferred the larger size of the false hosts. Ullyett, on the other hand, holds that "any 'attack' on the sand grain . . . might be attributable to this (host-odor) stimulus and not to any actual preference for the sand-grain on account of size alone." In connection with the present experiments, however, preliminary tests, in which ground host puparia were mixed with the grain in order to lessen the odor-stimulus of the host to the searching parasites, showed no appreciable reduction in parasitization.

Evidence shows that the effect of contaminated grain is to keep the parasites from depositing their eggs. They apparently find and sting approximately half as many hosts as they would in clean barley. Thus, while the percentage of parasitization varies strikingly in tests with clean and contaminated barley, the percentage of hosts stung in these tests, varies much less. Although contamination of the barley is probably caused by tarsal secretions of the insect, the actual mechanism of the contaminated grain and its exact effect on the parasite, remain to be worked out.

DISCUSSION

The process of parasitization may be considered as divided into three phases: (1) host-finding, (2) host selection, and (3) host suitability. Host-finding consists in the finding of the environment containing the host and the finding of the host within the environment.

While the environment-finding procedure is still obscure, it is, in most cases, certainly not haphazard; rather, it must be very similar to the host-finding—host-selection—host-suitability complex. The processes involved may therefore be classified similarly into (1) environment-finding, (2) environment-selection, and (3) environment-suitability.

Environment-finding and environment-selection are probably similar, in general, to host-finding and host selection. Several authors have recognized the important part played by the environment in influencing these two phases of parasitization. Salt (1935, p. 414) states that:

> "Now it is certain that some parasites, and probable that many more, are first attracted not to a particular host but to a certain type of environment. By selecting a particular environment in which to search for hosts, and neglecting other places, the parasite restricts the number of potential host-species that it will meet, and so limits the number of species on its list of hosts. This, if it is host selection at all, might be distinguished as an oecological selection of hosts."

Flanders (1937) has found that environmental selection operates in the genus *Trichogramma* in such a way as to cause the species *evanescens*, *embryophagum*, and *semblidis* to occur in different habitats, even though hosts suitable for each species occur in all habitats.

Laing (1937) has reviewed the literature on cases of parasites searching, first, for a certain environment, and then for the host within the environment, and has concluded that many parasites "when they search for hosts, appear to find first a particular type of environment, and then proceed to seek the hosts themselves." Laing has also demonstrated experimentally that *Alysia manducator* and *Mormoniella vitripennis* are attracted to an environment likely to contain their hosts, by qualities of the environment itself, independent of the presence of hosts. Environmental suitability has not been discussed, as such, either by the workers named above or by any others with whose work the writer is familiar. Once the host has been found, the environment has been assumed to have little or no further effect on the parasite; the selection of the host has, thus far, usually been shown to depend on the qualities of the host itself. The present case of environmental unsuitability, in which the contaminated environment renders the host

unsuitable for parasitism, is apparently unique. Obviously, environmental suitability may be of the utmost importance, especially in laboratory studies; and its effect, if any, should be considered and investigated in all highly accurate studies. Ullyett says (1936, p. 264):

> "We have yet to define and determine the effects of abnormal environments. It seems not unlikely that the majority of our laboratory experiments, however closely they appear to conform to what we consider optimum conditions for the insect subject, may contain some abnormal element of which we know nothing but which, nevertheless, duly affects the delicate organism with which we are dealing."

SUMMARY

Mormoniella vitripennis (Walker), a pupal parasite of the housefly, *Musca domestica* L., was used in tests in which the environment consisted of fly puparia dispersed through barley grains. The parasites so contaminate the grain by running over it in their search for their hosts that eventually no parasitization is obtained in tests in which this grain is used. When contaminated grain was cleaned with water and used in other tests, normal parasitization was obtained.

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NOTES ON AGRILUS WITH DESCRIPTIONS OF TWO NEW SPECIES

(Buprestidae: Coleoptera)

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It is the idea in this paper to figure the male genitalia of the North American species of *Agrilus* not illustrated to date. Since the Agrili are quite selective as to host, records of capture may lead to a more definite establishment of plants in which the species breed.

Agrilus cavifrons Water.

Figure 6

Waterhouse, Biol. Centr.-Amer., Coleopt., vol. 3, pt. 1, p. 189, 1899; Knull, Ohio Jour. Sci., 37(5): 305, 1937.

Male.—Form strongly cuneiform, bronzy brown above, cupreous beneath; pubescence of elytra forming an irregular design.

Head with a broad deep depression covering the entire front, the concavity containing five small smooth depressions arranged in a circle; surface of vertex coarsely punctured, front clothed with short pubescence obscuring surface; antennae extending past middle of pronotum when laid along margin, serrate from the fourth segment.

Pronotum wider at base than at apex, widest at middle; sides broadly rounded in front, sinuate at base; when viewed from the side, marginal and submarginal carinae joined back of middle; anterior margin strongly sinuate, median lobe broadly rounded; base strongly emarginate at middle of each elytron, median lobe truncate in front of scutellum; disk with broad deep triangular depression, widest in rear, a deep lateral depression each side, prehumeral carinae short, well indicated; surface irregularly coarsely punctured, finely granulose area in front of scutellum, depressions with short pubescence. Scutellum finely granulose, transversely carinate.

Elytra wider than base of pronotum, widest near base; sides strongly constricted back of base, expanded back of middle, obliquely narrowed, sinuate near obtusely rounded apices, apices serrulate, disk convex, basal depressions deep, each elytron with a strong, smooth, sinuate longitudinal costa which extends from humerus to apex, another short straight costa on outside back of middle; surface coarsely irregularly punctured.

Abdomen beneath irregularly punctured; last ventral with longitudinal carina, carina not projecting, a depression each side at apex; first two ventrals strongly convex, not flattened. Prosternal lobe strongly declivous, anterior margin broadly rounded. Anterior and middle tibiae arcuate, mucronate on inner margin at apices; posterior tibiae straight, not mucronate. Posterior tarsi only slightly shorter

than tibiae. Tarsal claws cleft near tip on anterior pair of legs, cleft deeper on second pair and deepest on posterior pair, inner tooth not turned inward.

Length 10.5 mm.; width 3 mm.

Female.—Differs from male by apical spines of first two pairs of tibiae being very short.

According to Fisher's key[1] the species would run to *A. lucanus* Fall. It can be separated by the carinate last ventral abdominal segment.

Since I recorded this species as occurring in our fauna, Dr. K. G. Blair kindly compared a specimen with the type in the British Museum. Specimens were collected on desert hackberry (*Celtis pallida* Torr.), the host plant, in the Santa Catalina Mts., Santa Rita Mts. and at Florence, Ariz., in Aug. and Sept.

Agrilus palmerleei n. sp.

Figure 3

Male.—Robust, elongate; head and pronotum brilliant cupreous; elytra piceous; ventral surface and legs cupreous.

Head with longitudinal groove extending from occiput to middle of front; surface coarsely punctate becoming rugose on occiput, pubescence inconspicuous; antennae not reaching middle of pronotum when laid along side margins, serrate from the fourth segment.

Pronotum wider than long, base and apex of about equal width, widest in front of middle; sides broadly rounded in front, sinuate near base; when viewed from the side, marginal and submarginal carinae joined at base; anterior margin nearly straight; basal margin emarginate at middle of each elytron, median lobe truncate in front of scutellum; disk convex, with two median depressions, a strong oblique lateral depression on each side, prehumeral carinae short; surface transversely reticulate, pubescence inconspicuous in all but lateral depressions. Scutellum transversely carinate.

Elytra at base wider than base of pronotum; sides expanded at base, constricted in front of middle, widened back of middle, then gradually narrowed to rounded apices, margins serrulate back of middle; disk flattened, each elytron with a longitudinal costa extending from near basal depression to near apex; surface finely imbricate, pubescence inconspicuous.

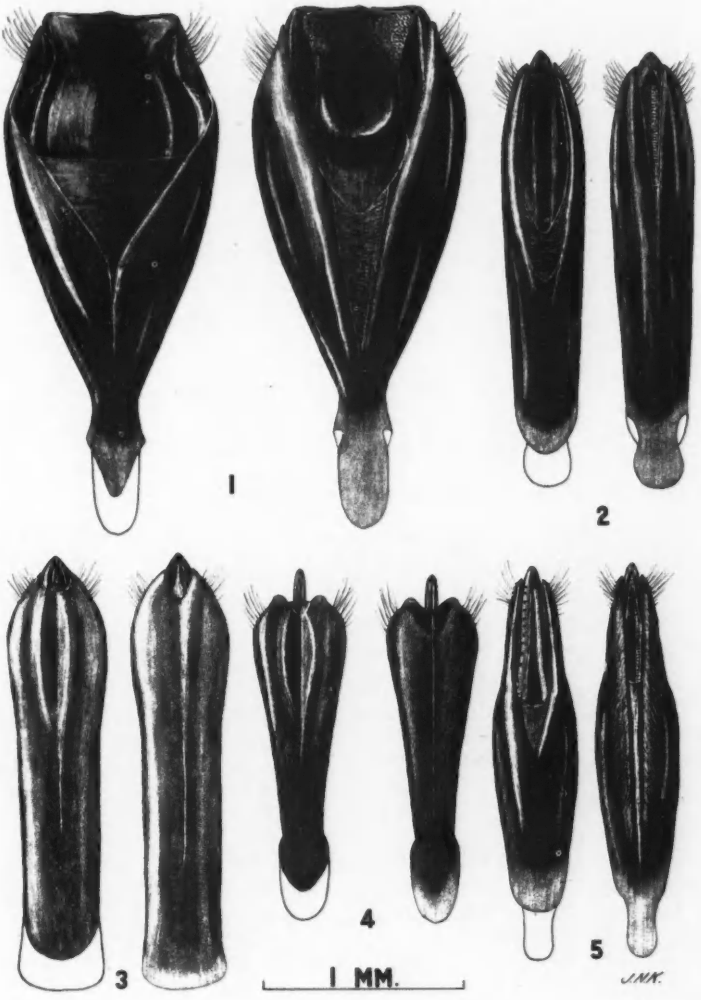
Abdomen beneath finely granulose, pubescence very short; first two segments convex at middle, not modified; pygidium without projecting carina. Prosternum pubescent, pubescence not extending along median ventral area; prosternal lobe broad, strongly emarginate in front; prosternal process with sides parallel to behind coxal cav-

[1]W. S. Fisher, U. S. National Mus. Bul. 145, pp. 1–347, 1928.

EXPLANATION OF PLATE I

Male genitalia of *Agrilus;* the figure on the left represents the dorsal surface, and the one on the right represents the ventral area.

FIGURE 1, *snowi* Fall; 2, *lucanus* Fall; 3, *palmerleei* n. sp.; 4, *townsendi* Schffr.; 5, *limpiae* Knull.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1 MM.
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J.N.K.

ities, then acutely narrowed to apex. Tibiae on first two pairs of legs mucronate on inner margin at apex. Posterior tarsi shorter than tibiae, first segment about as long as following segments together. Tarsal claws similar on all feet, cleft near middle, inner tooth nearly as long as outer one and not turned inward, tips distant.

Length 9.5 mm.; width 2.4 mm.

Holotype male described from a specimen in the collection of the writer labeled Huachuca Mountains, Ariz., July 15, 1937, D. J. & J. N. Knull collectors. This species runs to *A. townsendi* Fall in Fisher's key. It can be distinguished by being more elongate, elytra less evidently pubescent, pronotum proportionately longer, prehumeral carinae joining at base, structure of the posterior tarsi and form of genitalia.

Agrilus fuscipennis Gory

Adults were taken on persimmon (*Diospyros virginiana* Linn.) foliage at Otway and Shawnee State Forest, Ohio, June 8–10, 1943; these are the most northern records to date.

Agrilus cliftoni Knull

On June 28, another specimen of this species was collected along Clear Creek, Hocking Co., Ohio. A closer examination shows that all tibiae are mucronate on inner sides at apices. This would place the species next to *A. geminatus* (Say) according to Fisher's key.

Agrilus snowi Fall

Figure 1

Specimens of this rare species were collected on palo verda (*Parkinsonia microphylla* Torr.) at Globe, Ariz., Sept. 9, 1941, by Mr. F. H. Parker.

Agrilus costipennis Fisher

Collected from the foliage of hackberry (*Celtis mississippiensis* var. *reticulata* Sarg.) in the Davis Mts., Tex., from June 19 to July 5. It was collected also in the Chisos Mts., Tex., July 9 and the Chiricahua Mts., Ariz., June 19. Anterior and middle tibiae of the females are not mucronate on the inner margin at apices as they are in the males.

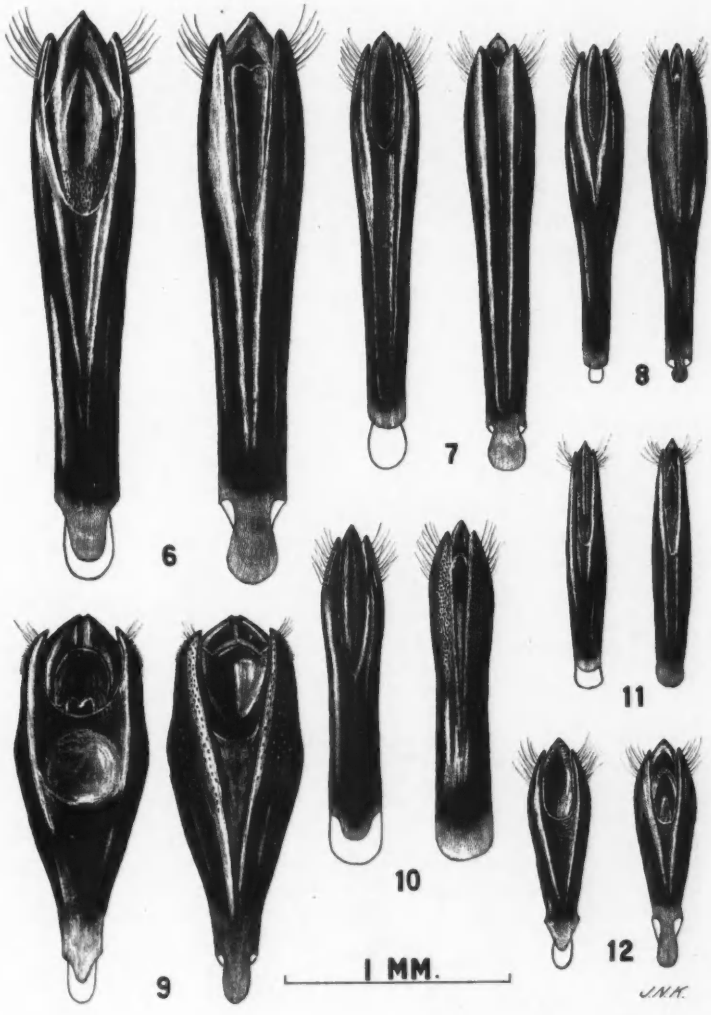
Agrilus baboquivari Fisher

Adults were collected from desert hackberry (*Celtis pallida* Torr.) in which the species breeds in Santa Rita Mts., Tucson Mts., and at Florence, Ariz., in Aug.

EXPLANATION OF PLATE II

Male genitalia of *Agrilus;* the figure on the left represents the dorsal surface, and the one on the right represents the ventral area.

FIGURE 6, *cavifrons* Water.; 7, *fisherianus* Knull; 8, *wenzeli* Knull; 9, *santaritae* Knull; 10, *amelanchieri* n. sp.; 11, *parapubescens* Knull; 12, *exhuachucae* Knull.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1 MM.
J.N.K.

Agrilus ventralis Horn

Figure 15

Three specimens of this rare species are before me from Carlsbad Cavern, N. Mex., May 5, 1934, Phoenix, Ariz., April 12, 1931, both E. D. Ball collector, and Baldwin Lake, Cal., June 27, 1941, collected by the writer and Mrs. Knull.

In the female from New Mexico, the second ventral abdominal segment is only slightly produced into an arcuate lobe in middle. This is quite different from the well developed lobe on the second and third segments of the male.

Agrilus obolinus Lec.

Specimens were collected from the foliage of hackberry (*Celtis*) at Brownsville, June 8, and Davis Mts., Tex., June and July.

Agrilus obsoletoguttatus Gory

Specimens were reared from cut branches of buckeye (*Aesculus glabra* Wild.) collected at Columbus, Ohio.

Agrilus lautuellus Fisher

Collected from black persimmon (*Diospyros texana* Scheele) in which the species breeds, in Uvalde Co. and Val Verde Co., Tex., May and June.

Agrilus ornatulus Horn

Collected from the foliage of soapberry (*Sapindus drummondi* Hook & Arn.) in the Davis Mts., Tex., in June.

Agrilus coeruleus (Rossi)

This species is well established at Columbus, Ohio. Adults were collected in May and June around ornamental plantings of honeysuckle (*Lonicera* sp.) in which the insect breeds.

Agrilus amelanchieri n. sp.

Figure 10

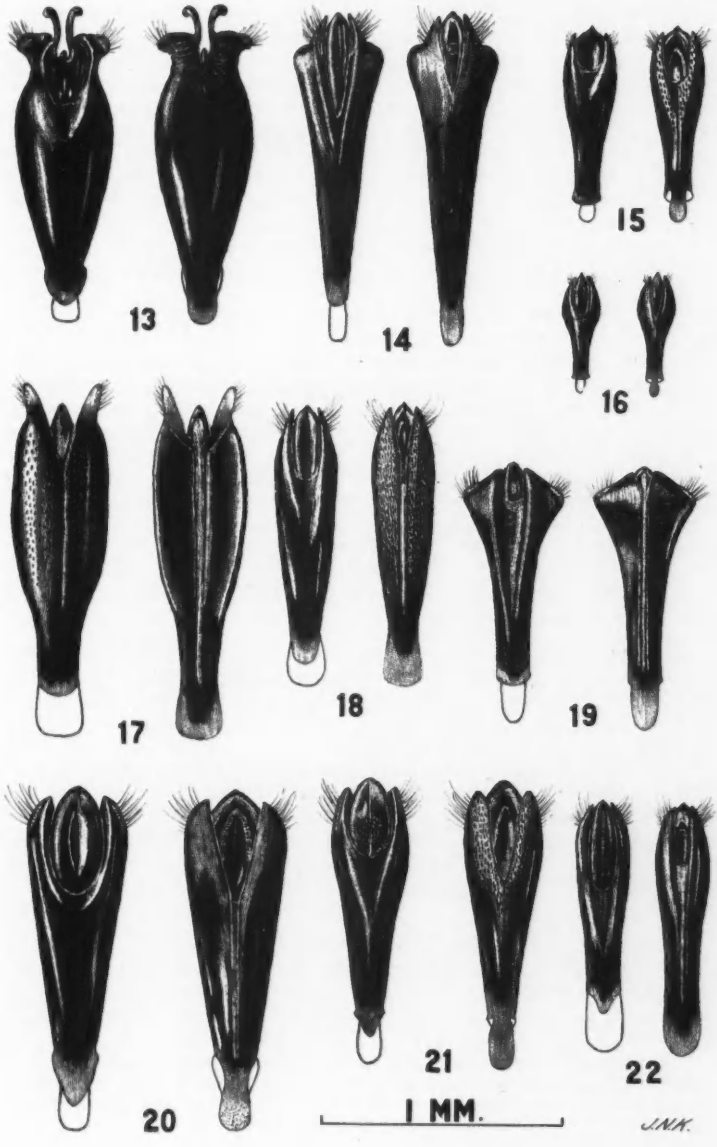
Male.—Form of *A. arcuatus* (Say); head with front green, vertex and pronotum brilliant cupreous; elytra piceous; ventral surface cupreous.

Head convex, slightly depressed on top; surface granulate on front becoming finely rugose on vertex, pubescence short; antennae reaching middle of pronotum when laid along side, serrate from the fourth segment.

EXPLANATION OF PLATE III

Male genitalia of *Agrilus;* the figure on the left represents the dorsal surface, and the one on the right represents the ventral area.

FIGURE 13, *mimosae* Fisher; 14, *parkeri* Knull; 15, *ventralis* Horn; 16, *cercidii* Knull; 17, *osburni* Knull; 18, *viridescens* Knull; 19, *neabditus* Knull; 20, *duncani* Knull; 21, *shoemakeri* Knull; 22, *neoprosopidus* Knull.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Pronotum wider than long, wider at base than at apex, widest in middle; sides broadly rounded in front, sinuate near base; when viewed from the side, marginal and submarginal carinae joined at base; anterior margin slightly sinuate, median lobe broad; basal margin emarginate at middle of each elytron, median lobe truncate in front of scutellum; disk convex, with two median depressions and one deep oblique lateral depression on each side, prehumeral carinae one-third length of pronotum, sharply defined; surface transversely finely rugose, pubescence inconspicuous. Scutellum transversely carinate.

Elytra at base wider than base of pronotum, sides subparallel at base, constricted in front of middle, expanded back of middle, broadly rounded posteriorly to rounded apices, margins serrulate back of middle; disk convex, a strong basal depression each side; surface imbricate, pubescence inconspicuous.

Abdomen beneath finely granulose, pubescence short; first segment somewhat flattened at middle, second segment convex, suture between segments barely indicated at sides; pygidium without projecting carina. Prosternum densely pubescent, hairs extending to first abdominal; prosternal lobe broad, emarginate in front; prosternal process with sides parallel to behind coxal cavities, then obliquely narrowed to acute apex. Tibiae on all pairs of legs mucronate on inner margin at apices. Posterior tarsi shorter than tibiae, first segment nearly as long as three following segments combined. Tarsal claws similar on all feet, cleft near middle, inner tooth stouter and somewhat turned inward, the points not touching.

Length 5.8 mm.; width 1.6 mm.

Female.—Differs from the male by lacking mucronate tibiae and line of median ventral pubescence.

Holotype male and allotype female collected in copulation at Mont Alto, Pa., June 21, 1931, by the writer. Paratypes reared June 6–11, 1926, from shad bush, (*Amelanchier canadensis* (L.) Med.) collected in Clark's Valley, Dauphin Co., Pa. Type material in collection of writer.

This is the species recorded by me[2] as *A. arcuatus* (Say), which it superficially resembles. The mucronate posterior tibiae will separate it. It should stand next to *A. crataegi* Frost; it can be separated by the color of head and pronotum as well as shape of pronotum, presence of strong prehumeral carinae, and anterior tarsal claws turned inward.

Agrilus mimosae Fisher

Figure 13

Adults were collected in Arizona: Globe, June 10–20, F. H. Parker; Patagonia, June 24, Santa Catalina Mts., June 7, A. A. Nichol; Tucson, May 23, E. D. Ball; Huachuca Mts., July 28, J. S. Hine; Quinlin Mts., July 25, E. D. Ball; Chiricahua Mts., June 20, A. A. Nichol. Texas: Davis Mts., May 25–July 25, D. J. & J. N. Knull.

Mr. Fisher kindly compared a specimen with the unique female type. The male differs from the female by having a median ventral line of pubescence extending from prosternum to second abdominal segment.

[2]J. N. Knull, Ent. News, V. 41, p. 84, 1930.

First and part of second abdominal segments slightly channeled at middle. Front of head green. Tibiae of first two pairs of legs mucronate on inside at apices.

Agrilus neoprosopidus Knull

Figure 22

In addition to the holotype, two males and a female of this species have been taken at Brownsville, Tex. In the female the front of head is bronze and the tibiae of the first two pairs of legs are not mucronate on inside at apices.

Agrilus pseudofallax Frost

Adults were collected at Columbus, Ohio, in June and July on foliage of honey locust (*Gleditsia triacanthos* Linn.) in the branches of which the species breeds.

Agrilus barberi Fisher

Adults were taken by the writer and Mrs. Knull on locust (*Robinia neo-mexicana* Gray) in which the species breeds, in Arizona at Williams, Aug. 9; Prescott, July 14; Oak Creek Canyon, July 13–Aug. 15 and Hualpai Mts., Aug. 6.

THE PERMEABILITY OF NATURAL MEMBRANES, by HUGH DAVSON and JAMES FREDERIC DANIELLI, with a foreword by E. NEWTON HARVEY. Pages x+361, 73 figures, 5¾ x 8½ inches. Published by THE MACMILLAN COMPANY, New York, and THE UNIVERSITY PRESS, Cambridge, England. 1943. Price, $4.75.

This book presents a general survey of the field of permeability, and contains material essential for students of medicine, physiology, biochemistry, botany, and zoology. Entomologists interested in insect physiology or toxicology will find this book particularly helpful in explaining how insecticides and other materials enter the tissues of an insect. The book contains a great many literature references, which enable the reader to explore the subject further with a minimum of trouble.

The scope of the book is indicated by the chapter headings: 1, Significance of Permeability Studies; 2, Methods of Studying Membrane Permeability; 3, Equilibrium Conditions of Cells; 4, Some Equations Used in Permeability Studies; 5, The Nature of the Process of Diffusion; 6, The Structure of the Plasma Membrane; 7, The Interpretation of Permeability Measurements; 8, Permeability to Non-Electrolytes; 9, Permeability to Gases; 10, Permeability to Water; 11, Permeability to Proteins and to Large Lipoid Molecules; 12, Permeability of Erythrocytes to Ions; 13, Permeability to Ions of Cells Other than the Erythrocyte; 14, Permeability to Weak Electrolytes and Dyes; 15, Impedance and Potential Measurements and Permeability; 16, The Effect of Narcotic Substances on Permeability; 17, The Effect of Temperature on Permeability; 18, Haemolysis; 19, Membrane Permeability in Relation to Secretion; 20, The Kidney; 21, Theories of Cell Permeability; Appendix A, The Theory of Penetration of a Thin Membrane.

This is the first general book on the important subject of permeability that has appeared in the past ten years. Its emphasis is mainly quantitative, as the present-day experimental work in permeability is largely in this direction. This emphasis has been made possible by the recent advances in the field of surface chemistry and the structure of liquids and solids. The contributions of many workers have been drawn upon in achieving a description of how various materials penetrate a membrane. This book marks a big step in our progress in understanding the inner workings of the living organism.—D. J. B.

CULEX (MELANOCONION) ATRATUS THEOBALD IN FLORIDA; A NEW CONTINENTAL NORTH AMERICAN RECORD, WITH NOTES ON THE OTHER MELANOCONIONS OF THE SOUTHEASTERN UNITED STATES

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Fourth Service Command Medical Laboratory,
Fort McPherson, Georgia

A single male of *Culex* (*Melanoconion*) *atratus* Theobald, the first known North American record of the species, was taken December 9, 1942, in a light trap on Boca Chica Key, Florida. Other mosquitoes represented in the same collection are as follows: 59 ♂ and 2675 ♀ *Aedes taeniorhynchus* (Wied.), 3 ♀ *Aedes sollicitans* (Walk.), 4 ♀ *Anopheles atropos*, D. & K., 1 ♂ and 4 ♀ *Deinocerites cancer* Theob., 1 ♀ *Culex bahamensis* D. & K., and 2 ♀ *Culex* (*Melanoconion*) sp. which may be *Culex atratus*.

The male *C. atratus*, although damaged, was positively identified by the hypopygium which agrees closely with specimens borrowed from the United States National Museum. Dyar (1928) records the species from the Virgin Islands (St. Thomas), Jamaica, Cuba, and Haiti.

The discovery of *atratus* on the Lower Florida Keys is not surprising when one considers the many other Antillean animals and plants which have succeeded in reaching those islands and establishing themselves there. Boca Chica Key is near Key West where shipping from the West Indies is continually arriving, and the present species could have been accidentally introduced by this means or arrived by more natural means across the channel from Cuba. Dyar states that the species breeds in "ground pools," and there are numerous freshwater ponds and pools on many of the Lower Keys which are probably suitable for its development.

Several other West Indian species have been found on the Lower Keys, notably *Anopheles albimanus* Wied., an important vector of malaria, which was introduced into Key West in 1904, but failed to become established. It very probably arrived as a waif on some ship. *Culex bahamensis*, on the other hand, has established itself on several of the Keys and probably represents a natural migrant. Further collecting in some of the more inaccessible places will probably add other species to our list.

The genitalia of *Culex atratus* are quite characteristic and differ greatly from those of the other Melanoconions found in the Southeast. Dyar's figure of the terminalia is drawn on too small a scale to show all the parts distinctly. The present description of the genitalia supplements that given by Dyar.

The larvae have not as yet been collected on the Keys and none were available. Lt. Col. Willard V. King examined one larval slide

[1]Second Lieutenants, Sanitary Corps, Army of the United States.

labeled *Culex atratus* at the United States National Museum, but stated that it was too badly damaged to describe. Since Dyar's works are not too widely available, his characterization of the larva is repeated here.

Larva.—Head transverse, bulging on the sides; antennae large, a tuft of hair at the outer third, the part beyond slender, basal part spinulated. Head hairs, upper a small tuft of five, lower a long single hair. Lateral comb of the eighth segment of many small spines in a patch four rows deep. Air-tube long and slender, straight, a little flared at the base, about nine times as long as wide, the pecten reaching the basal third, followed by five short tufts, decreasing in number of

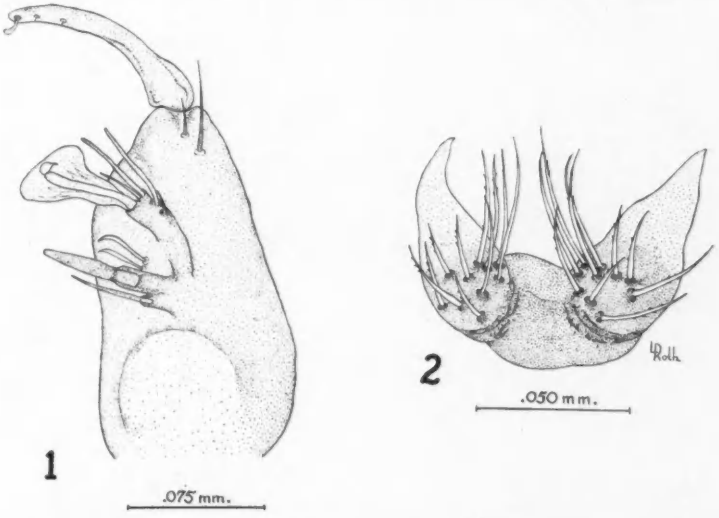

FIGURE 1. Sidepiece of the terminalia of *Culex atratus*. Inner view; outer setae and pilosity not indicated. 2. Lobes of the ninth tergite of *Culex atratus*. Figs. 1 and 2 drawn with the aid of an ocular grid.

hairs outwardly, but all of about equal length; a single hair and a small two-haired tuft on the side. Skin pilose. Anal segment longer than wide, ringed by the plate, the ventral brush posterior; dorsal tuft a long hair and a long and two short hairs on each side. Anal gills very small, not as long as the width of the segment.

Hypopygium (figs. 1 and 2).—Side piece elliptical, convex outwardly. Basal and apical divisions of the subapical lobe well separated; basal division of the lobe columnar, with a slender lower seta from its base; upper seta acuminate, but stout and rather rod-like; apical division curved from the base of the basal with a broad ribbed leaf from its tip, behind which arises a stout recurved seta. (This seta is constricted just before the recurved tip in our Floridian specimen,

but the Antillean ones examined lacked this constriction.) Two conspicuous slender setae arise on the outer side of the apical division each with a smaller, inconspicuous seta from near its base. The clasper slender, uniform, the base a little enlarged with a somewhat clavate subterminal seta. In our specimen, three apically broadened setae arise from the side piece between the apical and basal divisions of the subapical lobe, and are partly hidden by the basal portion. (In the Antillean specimens, however, the number of these setae varied from 4 to 6.) Tenth sternites narrow, provided with teeth giving a comb-like appearance. Ninth tergites pear-shaped, tapering to a point, and with a number of barbed setae arising from conspicuous tubercles on the basal half. Mesosomal plate a stout, curved, simple blade.

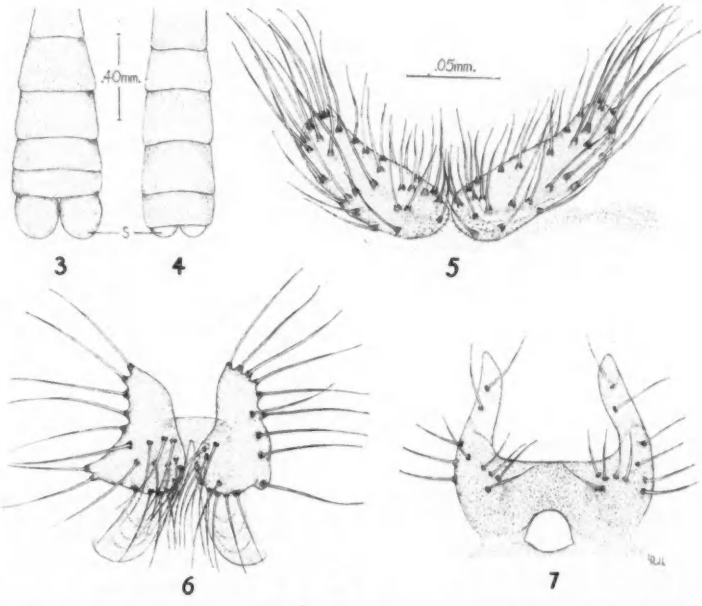

FIGURE 3. Dorsal view of the abdominal segments of *Culex peccator*. S=side-pieces of the terminalia. 4. Dorsal view of the abdominal segments of *Culex erraticus* (somewhat similar in *Culex pilosus*). 5. Lobes of the ninth tergite of *Culex erraticus*. 6. Lobes of the ninth tergite of *Culex peccator*. 7. Ninth tergite of *Culex pilosus*.

All figures outlined with the aid of an ocular grid. Figs. 5, 6, 7, drawn to the same scale.

Culex atratus raises to four the number of Melanoconions found in Florida. The others are *Culex erraticus* (D. & K.) and *C. peccator* D. & K., both also found in the other southeastern states (Georgia, Alabama, Mississippi, Louisiana, Arkansas, Tennessee, North Carolina,

and South Carolina), and *Culex pilosus* (D. & K.) which has been recorded from all these states except Arkansas and Tennessee.

As pointed out by King, Bradley, and McNeel (1942) the "adults of the Melanoconion species cannot be identified with certainty except by characters of the male terminalia . . . " (p. 70). However, it might be well to add that the male of *C. peccator* may be distinguished macroscopically from the other species by the fact that the abdominal segments gradually increase in width and the sidepieces of the terminalia are large and bulbous and well exposed (fig. 3). The other Melanoconions have the margins of the abdominal segments nearly parallel and the comparatively small sidepieces are more or less hidden by the last abdominal segment (fig. 4).

The most distinctive character of the terminalia is the shape of the lobes of the ninth tergites, although other differences are present. Figures of the entire genitalia are already to be found in the literature (Dyar, 1928; Matheson, 1929, *et al.*), but the ninth tergites are seldom clearly indicated. Therefore it appears worthwhile to include drawings of these structures in the present paper. King and Bradley (1937) have listed and discussed the synonymy of the subgenus *Melanoconion* in the United States, and their paper includes three other species, *Culex inhibitator* D. & K., *Culex abominator* D. & K., and *Culex anips* Dyar.

The key to the male terminalia of the dark-legged species of *Culex*, given by King, Bradley, and McNeel (1942), is modified here to include the new form *Culex atratus*. The descriptions of the ninth tergites have been amplified, while that portion of the key dealing with the subgenus *Culex* is omitted:

1. Tenth sternite with an apical tuft of short bristles or spines....Subgenus **Culex**
   Tenth sternite comb-shaped apically, with a row of fairly stout teeth.....2
2. Subapical lobe of sidepiece with a distinct division; mesosomal plate with a long, curved basal arm (basal hook), directed ventrally (except in *Culex atratus*).....Subgenus **Melanoconion**
   Subapical lobe not distinctly divided; mesosomal plate without a basal hook; outer end of mesosomal plate studded with small tubercles.
   Subgenus **Neoculex, Culex apicalis**
3. Apical division of the subapical lobe of the sidepiece with a distinct broad flat leaf.....4
   Apical division of the subapical lobe lacking an expanded leaf but with several rod-like filaments; lobes of the ninth tergite finger-like projections from the corners of a broad, spicular plate, which has a central oval or irregularly ovate lacuna; one or two smooth setae on each lobe and several grouped on the posterior corners of the plate (fig. 7); apical swelling of the clasper cap-shaped, tapering abruptly.....**Culex pilosus**
4. Clasper gradually tapered with very little apical swelling.....5
   Clasper greatly enlarged apically with the outer and front margin of the expanded quadrangular portion hirsute, the stem stout and constricted near the middle; lobes of ninth tergite roughly triangular, approximate, the outer and lower margins and basal portion of each with long, smooth setae arising from conspicuous tubercles (fig. 6).....**Culex peccator**
5. Lobes of the ninth tergite ovate, prominent, with numerous smooth setae arising from prominent tubercles; numerous small spicules on the lower base of each lobe (fig. 5).....**Culex erraticus**
   Lobes of ninth tergite somewhat pear-shaped with a number of barbed setae arising from the basal half (fig. 2); apical and basal portions of the subapical lobe well separated, the basal portion with an upper stout, rod-like seta and a slender lower one (fig. 1); mesosomal plate a stout, curved, simple blade.....**Culex atratus**

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King, W. V., and **Bradley, G. H.** 1937. Notes on *Culex erraticus* and related species in the United States. Ann. Ent. Soc. Amer., 30: 345–357.

King, W. V., Bradley, G. H., and **McNeel, T. E.** 1942. The mosquitoes of the Southeastern States. Misc. Pub. No. 336 (Revised), U. S. D. A.

Matheson, Robert. 1929. A handbook of the mosquitoes of North America. Springfield: Charles C. Thomas.

AN OUTLINE OF GENERAL PHYSIOLOGY, by L. V. HEILBRUNN. Pages xii+748, 135 figures, 6 x 9¼ inches. Published by W. B. SAUNDERS COMPANY, Philadelphia. Second edition, 1943. Price, $6.00.

Most entomologists, particularly those interested in ecology or in the action of insecticides, are well aware of the importance of an understanding of physiology and physiological techniques in the solution of their problems. Most courses and texts on physiology are concerned mainly with mammalian or human physiology, and treat the invertebrates only incidentally or not at all. The present book is one of the few good texts on general physiology which deals with invertebrates as well as vertebrates, and hence should be of particular value to entomologists.

As the title indicates, this book is essentially an outline. One of the objectives of the author has been to present a source book for the various branches of the subject. The discussions are usually brief, and the reader's attention throughout the book is directed to sources of additional information by means of footnote literature citations. The total number of these citations is about four thousand.

This second edition has the same general arrangement and chapter headings as the first edition. Space here will not permit a complete listing of the 42 chapter headings, but a brief outline will indicate the broad scope of the text. Following a brief introductory chapter outlining the nature of the subject, the early chapters deal with the statics of living systems: one chapter on cell morphology, five chapters on the chemical make-up of protoplasm, and six chapters on the physical properties of living systems (including the colloidal chemistry of protoplasm, surface phenomena, osmosis, and permeability). Then follow nine chapters on the various aspects of metabolism: nutrition, digestion, absorption, growth, respiration, secretion, and excretion. There are eight chapters on the physical aspects of vital activity: types of movement, muscle action, and the production of mechanical energy, heat, electricity, and light. The next ten chapters deal with the living organism in relation to its environment: three chapters on the effect of temperature, pressure, light, and chemical factors; the remaining chapters in this group deal with the various aspects of irritability and response to stimuli, including the physiology of nerve action, receptors, and tropisms. The two final chapters deal with cell division and senescence. At the end of the book are very complete author and subject indices.

The present volume is considerably larger than the first edition (748 as compared with 603 pages), and brings the account up to date. There is a great deal more material on the lower organisms (including insects), and information about such new topics as the vitamin needs of lower organisms, the relation of vitamins to oxidative processes, the localization of enzymes within various parts of the cell, and new techniques such as the use of tracer elements and the electron microscope. There are about twice as many literature citations as were in the first edition.

Dr. Heilbrunn is a professor of zoology at the University of Pennsylvania. He has done considerable research on various aspects of the physical chemistry of protoplasm and cell division, and is a leading authority in this field. He has also had experience in editorial work, which is manifest in the present carefully written and edited text. He has the viewpoints of both the research worker and the teacher, and these are reflected in the refreshingly different and often challenging style of his writing. It is well worth while for entomologists to become acquainted with the writings of such top-flight physiologists as Dr. Heilbrunn.—D. J. B.

THE NEOTROPICAL COCCID-TENDING ANTS OF THE GENUS ACROPYGA ROGER

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Recent studies by Bünzli (1935) have demonstrated the importance of ants of the genus *Acropyga* (subgenus *Rhizomyrma*) to the cultivation of coffee in Surinam. The ants (*Rhizomyrma paramaribensis* Borgmeier and *R. rutgersi* Bünzli) tend coccids[1] on the roots of the Liberian coffee trees and these coccids transmit an infectious phloëmnecrosis. This phloëmnecrosis in epidemic years caused a loss of 20–40 per cent of the coffee production in many fields in Surinam (Stahel, in Bünzli, p. 559). Earlier studies by Göldi (1892), Pickel (1927) and Costa Lima (1928) showed that coccids (*Rhizoecus coffeae* Laing) tended by other species of this subgenus caused severe injury to coffee trees in northeast Brazil. According to Donisthorpe (1936) a species of *Rhizomyrma* has recently been taken associated with a coccid at the roots of coffee in Colombia.

Incidental to studies on leaf-cutting or fungus-growing ants[2] I was able to collect and make observations on a number of known and new species of this hypogaeic ant genus with their coccids.[3] They confirm the much more extensive Brazilian and Surinam biological studies and also indicate that this ant-coccid association may be of importance to the cultivation of cacao as well as possibly other economically important plants such as banana. The collections and observations were made in Trinidad, Venezuela, British Guiana, Colombia, Panama and Haiti. In Trinidad the ants with their coccids were usually found about the roots of cacao, one of the most important crops in this British colony. On three occasions the coccids clearly were pastured on the roots of cacao while in six other instances they were pastured on roots under cacao, coffee, and banana which may have belonged to any one or to all of these plants. One collection of *Rhizomyrma* in British Guiana was of workers found tending coccids on the grass, *Axonopus compressus*. This is a widely used tropical pasture grass. In Venezuela a large colony of *Rhizomyrma* was found tending coccids on roots at the base of a banana clump. These ants with their coccids were discovered on

[1] *Rhizomyrma paramaribensis* tends the coccids *Rhizoecus coffeae* Laing, *R. caladii* Green, *R. moruliferus* Green, *Geococcus coffeae* Green, and *Pseudorhizoecus proximus* Green. *Rhizomyrma rutgersi* tends the coccids *Pseudorhizoecus proximus* Green, *P. migrans* Green, and *Pseudococcus radicis* Green.

[2] Most of the earlier studies were made while holding a National Research Fellowship in Biology at the Imperial College of Tropical Agriculture, Trinidad, B. W. I.

[3] Representative coccids from these collections are in the hands of Dr. Harold Morrison of the U. S. Department of Agriculture for identification. Specialists in insect groups are usually overburdened with material for identification. The common Trinidad type, a sketch of which appears in this paper, has been referred to as "*Eumyrmococcus* or to some other very closely allied genus," (Wheeler, 1935, p. 325).

roots of coffee in Haiti. Since coccids carried by these ants have been proved to be the vector of an important disease of coffee in Surinam, the findings here reported would suggest that the *Rhizomyrma*-coccid relationship be thoroughly investigated as a possible factor in disease of cacao, coffee and banana in other neotropical countries. Whether a disease is actually transmitted by the coccids or not, the loss of sap alone from the roots is of importance and must weaken the vitality of the trees.

The association between the ants and the coccids is not haphazard but a definite symbiotic arrangement. Not only are the ants and coccids usually, if not always, found together in the same tunnels, but the ants care for the coccids as they care for their own brood and in addition actually disseminate the coccids from place to place. It is quite possible that *Rhizomyrma* ants are obligate coccidophiles, in the New World at least.

These ants have become adapted to their mode of life in several ways. Living underground as they do, there has been a considerable loss of pigment, which loss has been greatest in the worker caste. This caste is pale yellow or brownish-yellow while the female is somewhat darker but never darker than brownish-yellow. Even the comparatively stable male caste is in *Rhizomyrma* only medium brown while in many genera of ants this caste is dark brown or black. Accompanying the loss of pigment in the worker has been a reduction in the eyes so that they have become mere vestiges, pin-points 0.02–0.06 mm. in diameter. The eyes in the female and male are of normal size and they swarm in the air in the usual fashion. The general habitus of the worker is a small to minute size with moderately short legs and no spines or other attenuations of the body which might impede their passage through the soil. All castes have long hairs on the clypeus, especially on the anterior margin, with one hair much the longest and extending well across the space between the closed mandibles and the clypeus. These hairs are doubtless useful in caring for, and carrying, not only their larvae but their coccids.

There are four subgenera of *Acropyga* (*Acropyga, s. str.*, *Atopodon*, *Malacomyrma* and *Rhizomyrma*) but only *Rhizomyrma* is recorded from the New World. The subgenera are separated chiefly on the characteristics of the mandibles, the number of antennal segments, and the geographical distribution, but all are closely related and the subgenus *Rhizomyrma* alone contains species running the gamut of mandibular and antennal characters. *Rhizomyrma* was established by Forel in 1893 (Trans. Ent. Soc. London, Part IV, pp. 347–348), as a subgenus of *Acropyga* with the worker characteristics of 7–11 segmented antennae, 2-segmented maxillary and 3-segmented labial palpi, long, narrow mandibles with 3–4 teeth on an extremely oblique border, extremely small eyes, no ocelli, frontal area triangular and distinct, antennae clavate, but otherwise like the other *Plagiolepidini*. The single female which Forel had seen lacked wings and was described merely as like the worker. The male caste was undescribed.

This paper brings together for the first time descriptions of all of the known species of *Rhizomyrma* in the New World. Some of the species are known only from specimens in European or South American

collections which are unavailable for study. Some are unusually hard to evaluate because of the variability in characters or subtle differences in proportions which are difficult to show by description or drawing. The original drawings of *R. rutgersi*, for example, show workers with such differences as to indicate that they belong to two species and I have had much trouble in determining whether certain Trinidad, Venezuela and British Guiana ants actually belong to this species.

The species are arranged in chronological order of their description with the new species at the last. The biology of the different species is treated at the end of the taxonomic description of each.

KEY TO THE NEOTROPICAL SPECIES OF ACROPYGA (RHIZOMYRMA) BASED ON THE WORKER[4]

1. Antennae 7–8 segmented....2
   Antennae with 8 or more segments....3
2 (1). Mandibles 3–4 toothed; length 1.8 mm.; head approximately as broad as long; antennal scape extending about three-fifths the distance to the occipit (Surinam, B. Guiana)....**paramaribensis**
   Mandibles 4-toothed; length 1.5–1.9 mm.; head 1.1 times longer than broad; dorsal surface of thorax plane (Trinidad)....**urichi**
3 (1). Antennae 8-segmented; mandible 4-toothed....4
   Antennae 8–11 segmented....7
4 (3). Head 1.3 times longer than broad (Panama)....**panamensis**
   Head 1.1 times longer than broad....5
5 (4). Length 1.2–1.3 mm.; antennal scape extending about three-fourths the distance to the occiput (Trinidad, Panama)....**kathrynae**
   Size larger, scape longer....6
6 (5). Length 1.3–1.8 mm.; antennal scape failing to reach occiput by about twice its distal diameter (Trinidad)....**berwicki**
   Length 1.7–1.9 mm.; antennal scape nearly attaining occiput (Colombia) **fuhrmanni**
7 (3). Antennae 8–9 segmented; mandible 3-toothed....8
   Antennae 9–11 segmented....9
8 (7). Length 1.4–1.6 mm.; funicular segments 5–6 much broader than long (Mexico)....**exsanguis**
   Length 2 mm.; funicular segments 5–6 as long as broad (Colombia)....**robae**
9 (7). Antenna 9-segmented; mandibles 3-toothed....10
   Antennae 9–11 segmented; mandibles 3–4 toothed....11
10 (9). Length 1.5 mm.; head longer than broad (Honduras, Panama)....**wheeleri**
   Length 2 mm.; head broader than long (Argentina)....**bruchi**
11 (9). Head as broad or broader than long....12
   Head longer than broad....20
12 (11). Head as broad as long....13
   Head broader than long....14
13 (12). Length 1.8–2.1 mm.; antennal scape exceeding occiput (Haiti) **mesonotalis**
   Length 2.2 mm.; antennal scape failing to reach occiput (Brazil)....**pachycera**
14 (12). Mandibles 3-toothed....15
   Mandibles 3–4 toothed....16
15 (14). Head 1.2 times broader than long; penultimate antennal segment barely broader than long (Barbados)....**marshalli**
   Head 1.0–1.1 times broader than long; penultimate antennal segment markedly longer than broad (Trinidad)....**trinitatis**
16 (14). Mandibles with 4 very small teeth; length 1.8–2 mm. (Haiti)....**parvidens**
   Mandibles with 3–4 well-developed teeth....17

[4]Because of the unavailability of some species it has been necessary to use in this key the variable characters of antennal-segment and mandibular-tooth numbers which are known for all. In some instances the key will serve only to limit identification to several species and recourse must then be had to the description and figures of these.

17 (16). Head quadrate, occiput not impressed, length 2.7–2.9 mm. (Trinidad) **quadriceps**
Head or size different....18
18 (17). Length 2.4–3.2 mm., mandibles 3–4 toothed: female 3.6–4.8 mm. long, male 2.8–3 mm. long, with 12-segmented antenna (Surinam, B. Guiana, Trinidad)....**rutgersi**
Smaller in all castes....19
19 (18). Antennal scape exceeding occiput; female 3–3.3 mm. long, antennae 9-segmented; male 2 mm. long, antenna 11-segmented (Brazil)....**decedens**
Antenna not attaining occiput; female 2.8 mm. long, antennae 11-segmented; male 1.3–1.6 mm. long, antennae 9-segmented (Brazil, Surinam) **pickeli**
20 (11). Antennal scape exceeding occiput....21
Antennal scape not attaining occiput....22
21 (20). Head 1.1 times longer than broad; diastema between the basal and third mandibular tooth marked (Brazil, B. Guiana)....**göldii**
Head 1.2 times longer than broad; diastema between the basal and third mandibular tooth less marked (B. Guiana)....**guianensis**
22 (20). Head barely longer than broad; length 1.7 mm. (thorax 0.55 mm.); eyes 0.04 mm. in diameter (B. Guiana)....**oko**
Head longer....23
23 (22). Length 2.4–2.8 mm. (thorax 0.6 mm.); eyes 0.06 mm. in diameter (B. Guiana)....**paludis**
Length 2.1–2.4 mm. (thorax 0.55–0.57 mm.); eyes 0.03 mm. in diameter (B. Guiana)....**donisthorpei**

Acropyga (Rhizomyrma) decedens (Mayr)

1887. *Brachymyrmex decedens* Mayr, Vehr. zool.-bot. Ges. Wien, 37: 521 (worker, female, male).
1892. *Brachymyrmex decedens* Göldi, Arch. Mus. Nac. Rio de Janeiro, 8: 176 (worker).
1905. *Rhizomyrma decedens* Emery, Bull. Soc. Ent. Ital., 37: 184, fig. (worker).
1914. *Rhizomyrma decedens* Wheeler, Bull. Amer. Mus. Nat. Hist., 33: 46 (worker).
1925. *Acropyga* (*Rhizomyrma*) *decedens* Emery, Genera Insectorum, Fasc. 183, p. 29 (worker, female, male).
1931. *Acropyga* (*Rhizomyrma*) *decedens* Borgmeier, Rev. Ent., 1: 105 (worker).
1931. *Acropyga* (*Rhizomyrma*) *decedens* Costa Lima, Bol. Biol., Fasc. 17, pp. 2–7 (worker).
1932. *Acropyga* (*Rhizomyrma*) *decedens* Costa Lima, Bol. Biol., Fasc. 21, pp. 65–68 (worker).
1935. *Acropyga* (*Rhizomyrma*) *decedens* Wheeler, Jour. New York Ent. Soc., 43: 322, 327, 328 (worker, female, male).
1936. *Acropyga* (*Rhizomyrma*) *decedens* Donisthorpe, Entomologist, 69: 110 (worker, female, male).

Worker.—Length 2–2.5 mm. Head, excluding mandibles, slightly broader than long, slightly broader in front than behind, broader than thorax, occipital margin nearly straight, faintly concave, anterior clypeal margin convex, eyes small, situated at a level with the posterior margin of the frontal lobes; mandibles 4-toothed, the teeth well developed and situated on a cutting margin nearly at right angles to the inner margin; antennae 9–11 segmented, scapes distinctly exceeding occipital angles, terminal segment distinctly longer than the preceding three taken together but shorter than the preceding four. Pilosity of scanty, long, upright hairs and abundant golden pubescence; yellow, mandibular teeth red-brown. (Mayr, Emery fig.).

Female.—Length 3–3.3 mm. Mandibles with 4 large, acute teeth; antennae in 3 females 9-segmented, in 7 females the 2nd funicular segment seems divided into two. (Mayr.)

Male.—Length 2 mm. Antennae 11-segmented, scape exceeding occiput, 1st funicular segment twice as long as broad. (Mayr).

Type locality.—Est. Rio de Janeiro, Brazil.

The types were taken by Göldi in 1892 at the roots of coffee with coccids. The coccids were referred to at the time as *Dactylopius* but have since been referred to as of the species *Rhizoecus coffeae* Laing.

Acropyga (Rhizomyrma) göldii Forel

Figure 14

1893. *Acropyga* (*Rhizomyrma*) *göldii* Forel, Trans. Ent. Soc. London, pp. 348–349 (worker).
1912. *Rhizomyrma goeldii* Forel, Mém. Soc. Ent. Belg., 20: 60 (worker).
1914. *Rhizomyrma goeldii* Wheeler, Bull. Amer. Mus. Nat. Hist., 33: 46 (worker).
1925. *Acropyga* (*Rhizomyrma*) *goeldii* Emery, Genera Insectorum, Fasc. 183, p. 29, Pl. I, fig. 15 (worker, female wing).
1931. *Acropyga* (*Rhizomyrma*) *göldii* Costa Lima, Bol. Biol., Fasc. 17, pp. 4–7 (worker).
1932. *Acropyga* (*Rhizomyrma*) *göldii* Costa Lima, Bol. Biol., Fasc. 21, pp. 65, 67–8 (worker).
1933. *Acropyga* (*Rhizomyrma*) *goeldii* Borgmeier, Rev. Ent., 3: 263 (female wing).
1935. *Acropyga* (*Rhizomyrma*) *goeldii* Wheeler, Jour. New York Ent. Soc., 43: 327 (worker).
1936. *Acropyga* (*Rhizomyrma*) *göldii* Donisthorpe, Entomologist, 69: 110 (worker).

Worker.—Length 2–2.3 mm. Head rectangular, broader than long, broader in front than behind; eyes very small, composed of two or three atrophied facets situated at the anterior third of the sides; mandibles 3–4 toothed, with three long, acute teeth and basally a minute denticle; antennae 10–11 segmented, antennal scapes slightly surpassing the occipital border, terminal segment of funiculus swollen, almost as long as the four preceding segments taken together, funicular segments 2–9 one one-fourth times broader than long. Thorax slightly concave longitudinally, mesonotum large and very elevated, meso-epinotal impression very distinct, epinotum rounded, declivous face much longer than the basal. Petiolar node very compressed, oval-rectangular. Legs very short, tarsi a little stout.

Smooth, shining, very finely and regularly punctate. Pilosity of erect, pale yellow, very fine, pointed hairs of irregular length which are abundant over the entire body, and a moderately abundant oppressed yellowish pubescence which is somewhat more abundant on the gaster; tibiae and scapes with very short hairs, oblique on the tibiae, upright on the scapes. Very pale yellow, slightly brighter than in *R. smithi*. (Forel).

Type locality.—Parahyba, Prov. Rio de Janeiro, Brazil.

Cultivating coccids on the roots of coffee.

The British Guiana workers described below agreed perfectly with specimens from Pará, Brazil, (Beebe) determined as *R. göldii* by Dr. W. M. Wheeler. They differ from Forel's description, however, chiefly in having the head distinctly longer than broad and the eyes larger (0.036 mm.), being composed of about six facets. The occipital margin is feebly impressed; the anterior clypeal margin feebly convex, the mandibles 4-toothed and the antennae are 10-segmented although several have indications of an eleventh segment forming, with the scapes

distinctly exceeding the occipital angles. The anterior face of the petiolar scale is convex, the posterior face is feebly concave and the dorsal crest is strongly convex.

Biology.—In virgin rain forest containing many Brazil nut trees (*Bertholletia* sp.) along the New River, in the neighborhood of 3° N. Lat. and 57° W. Long., Couratyne basin, British Guiana, a colony of this species was found July 18, 1936 (No. 576). The ants were tending the common Trinidad type of coccids on rootlets of small plants which were interwoven into the husk of a Brazil nut fruit lying on the ground. Under the husk was yellow sandy clay soil in which the ants had tunnels. The workers maintained the same solicitude for the coccids as did the Trinidad species and carried them off, dorsal side up and anterior end forward, between the ants' legs. Since only coccids were found here and no ant brood the workers evidently had their nest some distance off. Because this was merely a noon stop during strenuous traveling through falls and rapids by boat there was no time for investigating this association.

Acropyga (Rhizomyrma) göldii var. **columbica** Forel

1912. *Acropyga* (*Rhizomyrma*) *goeldii* var. *columbica* Forel, Mém. Soc. Ent. Belg., 20: 61 (worker).

1925. *Acropyga* (*Rhizomyrma*) *goeldii* var. *columbica* Emery, Genera Insectorum, Fasc. 183, p. 29.

Worker.—Length 2.2 mm. Mandibles 3-toothed; differing from the type of the species by the funicular segments 2–9 being about twice as broad as long and the tarsi somewhat less thickened. (Forel).

Type Locality.—Colombia, presumably, although no locality is stated.

Acropyga (Rhizomyrma) göldii var. **tridentata** Forel

1912. *Acropyga* (*Rhizomyrma*) *goeldii* var. *tridentata* Forel, Mém. Soc. Ent. Belg., 20: 61 (male, female).

1925. *Acropyga* (*Rhizomyrma*) *goeldii* var. *tridentata* Emery, Genera Insectorum, Fasc. 183, p. 29.

Female.—Length 3.3–3.5 mm. Head transversely rectangular, 0.7 x 0.57 mm., the occipital margin straight; eyes very small, situated at the anterior third of the head; mandibles with three long, acute teeth, without trace of a denticle; antennal scape surpassing occipital margin by twice its diameter, funicular segments slightly broader than long. Thorax and head equally broad, epinotum moderately convex, junction of basal and declivous surfaces indistinguishable. Wings blackish. Less shining and above all much more densely pubescent and punctate than in the typical *göldii*. Yellow with a touch of brown. (Forel).

Male.—Length 2.5–2.6 mm. Head squarish, slightly broader than long; mandibles 3-toothed; antennae 12-segmented, scape surpassing occipital margin by a fourth its length, middle segments of funiculus slightly broader than long. Thorax broader than head, exterior genital valves very large, very long, terminating in a long, flattened point, recurved above; there is a strongly and vertically recurved prolongation of the middle valves surpassing the border of the exterior

valves. More shining than in the female, otherwise similar. Dark brown, thorax and appendages clear brown. Wings tinted with blackish brown. (Forel).

Type Locality.—Panama? Taken by Christopherson from a nuptial flight.

Acropyga (Rhizomyrma) smithi Forel

1893. *Acropyga* (*Rhizomyrma*) *smithi* Forel, Trans. Ent. Soc. London, p. 349 (female).
1914. *Rhizomyrma smithi* Wheeler, Bull. Amer. Mus. Nat. Hist., 33: 46 (female).
1925. *Acropyga* (*Rhizomyrma*) *smithi* Emery, Genera Insectorum, Fasc. 183, p. 30 (female).
1935. *Acropyga* (*Rhizomyrma*) *smithi* Wheeler, Jour. New York Ent. Soc., 43: 328 (female).
1936. *Acropyga* (*Rhizomyrma*) *smithi* Donisthorpe, Entomologist, 69: 110 (female).

Female.—Length 2.0–2.2 mm. Head an elongate rectangle, much longer than broad, sides and posterior border straight, anterior margin of clypeus emarginate on each side, truncate and slightly concave in the middle, frontal carinae composed of an anterior portion in the form of a small, horizontal lobe and a posterior portion strongly divergent; frontal groove feeble but visible; eyes flat, very large, close to the anterior angles of the head; mandibles 3–4 toothed, feebly curved; antennae 7-segmented, scape extending to a level with the anterior ocellus, terminal funicular segment longer than the preceding 4 taken together, first funicular segment as long as the two following taken together, segments 4–5 broader than long. Pronotum not overhung by mesonotum, scutellum flattened, epinotum rounded. Petiolar node vertical, small, rectangular, the dorsal margin right-angled. Legs short

Very shining, smooth, finely and abundantly punctate. Hairs short, fine, pointed, scattered over body, lacking on scapes and tibiae; pubescence sub-appressed, pale yellow, short and widespread on body, legs and antennae. Pale yellow, mandibular teeth reddish, infuscated about ocelli and anteriorly on head. Wings lacking. (Forel).

Type Locality.—St. Vincent, British West Indies.

The single female was collected by H. H. Smith on Morne à Garou at an elevation of 1500 feet under the bark of a rotten log.

Acropyga (Rhizomyrma) pachycera Emery

1905. *Rhizomyrma pachycera* Emery, Bull. Soc. Ent. Ital., 37: 182–4, Fig. 44 (worker, female).
1914. *Rhizomyrma pachycera* Wheeler, Bull. Amer. Mus. Nat. Hist., 33: 46–47 (worker).
1925. *Acropyga* (*Rhizomyrma*) *pachycera* Emery, Genera Insectorum, Fasc. 183, p. 30 (worker, female).
1931. *Rhizomyrma pachycera* Borgmeier, Rev. Ent., 1:106 (worker).
1935. *Acropyga* (*Rhizomyrma*) *pachycera* Wheeler, Jour. New York Ent. Soc., 43: 327, 328 (worker, female).
1936. *Acropyga* (*Rhizomyrma*) *pachycera* Donisthorpe, Entomologist, 69: 110 (worker, female).

Worker.—Length 2.2 mm. Head, excluding mandibles, as broad as long (in figure), occipital margin straight, sides sub-parallel, anterior

clypeal margin convex; mandibles 4-toothed, masticatory margin oblique; antennae 9-segmented, scapes not reaching occipital margin. Pale yellow. (Emery).

Female.—Length 3.7 mm. Antennal scapes attain occipital angles, funicle somewhat more slender than in worker. Thorax as broad as head.

Type Locality.—Tacùrù Pucu (Alto Paranà), Brazil.

Acropyga (Rhizomyrma) exsanguis Wheeler

1909. *Rhizomyrma exsanguis* Wheeler, Boll. Lab. Zool. Gen. Agr. Portici, 3: 238 (worker).
1914. *Rhizomyrma exsanguis* Wheeler, Bull. Amer. Mus. Nat. Hist., 33: 46 (worker).
1922. *Acropyga (Rhizomyrma) exsanguis* Mann, Proc. U. S. Nat. Mus., 61: 53 (worker).
1925. *Acropyga (Rhizomyrma) exsanguis* Emery, Genera Insectorum, Fasc. 183, p. 29 (worker).
1935. *Acropyga (Rhizomyrma) exsanguis* Wheeler, Jour. New York Ent. Soc., 43: 327 (worker).
1936. *Acropyga (Rhizomyrma) exsanguis* Donisthorpe, Entomologist, 69: 110 (worker).

Worker.—Length 1.4–1.6 mm. Mandibles long, slender, uniformly curved, with parallel borders and 3 acute, oblique teeth. Antennae 8–9 segmented, scapes reaching almost to the occipital corners of the head, all funicular segments, except first and second much broader than long. Eyes extremely minute. Thorax as in *göldii*. Subopaque or finely shining. Hairs very sparse, pubescence not very abundant. Pale yellow. (Wheeler).

Mexico: Jalapa (F. Silvestri). This locality, near Vera Cruz in Latitude 19° 30′ N., is the northernmost record for this genus in the New World.

Acropyga (Rhizomyrma) fuhrmanni Forel

Figures 6, 11

1913. *Acropyga fuhrmanni* Forel, Mém. Soc. Sc. Neuchâtel, 5:12 (worker, female).
1925. *Acropyga (Rhizomyrma) fuhrmanni* Emery, Genera Insectorum, Fasc. 183, p. 29 (worker, female).
1935. *Acropyga (Rhizomyrma) fuhrmanni* Wheeler, Jour. New York Ent. Soc., 43: 327, 328 (worker, female).
1936. *Acropyga (Rhizomyrma) fuhrmanni* Donisthorpe, Entomologist, 69: 110 (worker, female).

Worker.—Length 1.7–1.9 mm. Head, excluding mandibles, rectangular, a little longer than broad, broadest in front, occipital margin slightly impressed medially; eyes more distinct than in *exsanguis*; mandibles 4-toothed, with a very distinct terminal border; antennae 8-segmented, scape not quite attaining occipital margin. Promesonotum as in *göldii*; petiolar node vertical, smaller than in *göldii*. Shining, finely punctate, pilosity abundant but passing gradually into an oblique pubescence. Pale yellow, mandibles brown. (Forel).

Female.—Length 2.5–2.7 mm. Antennae 8-segmented, scape reaching occiput and 2nd funicular segment as long as broad. Slightly dirty yellow, on the vertex, thorax and gaster a somewhat yellowish-

brown blotch. Wings brown, radial cell constant, one cubital cell, no discoidal cell. (Forel).

Type Locality.—Puerto de los Pobres, Cauca border, Dép. Antioquia, at an elevation of about 720 m.

Ants which I took in the same region (Rio Porce, R. Cauca tributary, Colombia, July 19, 1938) agree with Forel's description in general. The head of the worker is 1.1 times longer than broad, the occipital margin distinctly impressed, the anterior clypeal margin convex, the eyes 0.02 mm. in diameter, the mandibles with four well developed teeth arranged, however, on an oblique border, and the antennae 8-segmented with the scapes failing to reach the occipital corners by about their distal diameters. In side view the anterior pronotal margin is concave, the mesonotum is only feebly convex and the meso-epinotal impression is indistinct. The basal and declivous surfaces of the epinotum in side view are joined in a rounded angle. The petiolar scale in side view is thin, with a feebly convex anterior and a feebly concave posterior surface; from above and in front the dorsal surface is convex.

The female head, excluding mandibles, is rectangular, 1.1 times longer than broad, with occipital and anterior clypeal margins, subparallel sides, 4-toothed mandibles and 8-segmented antennae. The eyes are distinctive, being large, flattish, and situated less than a third their diameters from the mandibular insertions.

The undescribed male is 1.7 mm. long (thorax 0.5 mm.) has falcate mandibles with a single apical tooth and 9-segmented antennae. The petiolar scale is thin and conic in side view. The head is a dirty, dark brown, the gaster paler and the thorax still paler. The pubescence is moderately abundant and the hairs scanty.

The eggs are elliptical except for being slightly narrowed at one end and are 0.43 x 0.24 mm. (fig. 11). The larvae are moderately slender and have numerous hairs, some of which are simple, some trifid and some flattened and finely divided apically; these are lacking at the sutures (fig. 6).

This species was found twice at the El Hormiguero Mine, Rio Porce. Workers were taken July 19 from rotted wood in the base of a hollow stump 2 meters high but with only a shell 2–5 cm. remaining. About two-fifths of the sides were gone, leaving a protected area open to the north. The stump stood on the open, grassy area close to the Rio El Hormiguero, a small creek. In cells in the rotted wood from ground level to 15 cm. below were various ant colonies (*Anochetus*, *Prionopelta punctulata* Mayr, a female *Camponotus* (*Myrmobrachys*) *lindigi* Mayr, tiny myrmicines, and the *Rhizomyrma*). Termites, spiders and snails were also present. Later in the day a second colony was found a mile or two away but on an almost vertical slope in a ravine with densely wooded slopes. These ants were in wet clay (a disintegrated granite rich in feldspar) at a place with a slope of 70°–90°. The *Rhizomyrma* had formed innumerable tunnels of varying diameter up to 2 mm. On roots of ferns and small herbs piercing the tunnels were pastured coccids of the type tended by *R. berwicki* in Trinidad. Coccids and ant brood were just below the surface to 5 cm. depth. The coccids could be seen to flip their "tails" up and down as do those associated with Trinidad

species. The ants were comparatively active in their movements. In the tunnels were found many males, a few alate females and many pupal females. No queen was seen. The tunnels completely surrounded those of *Strumigenys*, *Pheidole* and colonies of a minute myrmicine.

Acropyga (Rhizomyrma) dubitata Wheeler and Mann

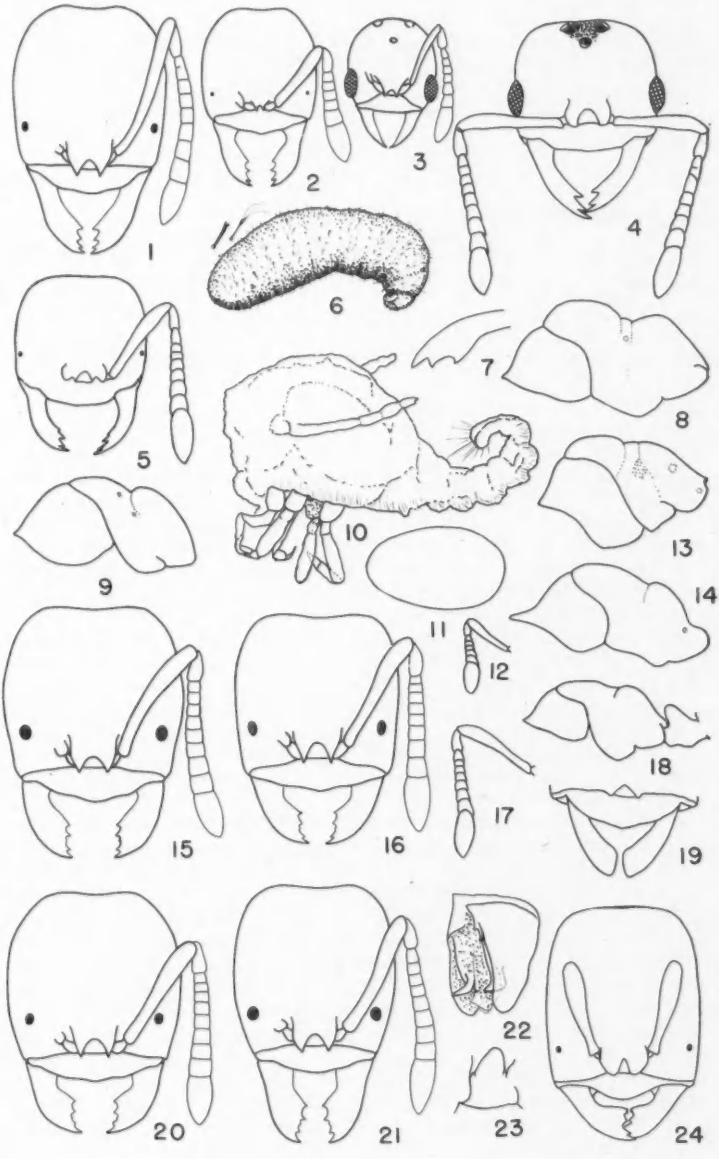
1914. *Rhizomyrma dubitata* Wheeler and Mann, Bull. Amer. Mus. Nat. Hist., 33: 47 (male).
1925. *Acropyga* (*Rhizomyrma*) *dubitata* Emery, Genera Insectorum, Fasc. 183, p. 29 (male).
1933. *Acropyga* (*Rhizomyrma*) *dubitata* Borgmeier, Rev. Ent., 3: 263 (male).
1935. *Acropyga* (*Rhizomyrma*) *dubitata* Wheeler, Jour. New York Ent. Soc., 43: 328 (male).
1936. *Acropyga* (*Rhizomyrma*) *dubita* Donisthorpe, Entomologist, 69: 110 (male).
1939. *Acropyga* (*Rhizomyrma*) *dubita* Donisthorpe, Proc. Ent. Soc. London, 8: 154 (male).

Male.—"Length 2 mm. Very similar to the male of *Acropyga*. Head a little broader than long, subrectangular. Eyes rather small, less than half as long as the sides of the head. Mandibles slender, distinctly tridentate. Clypeus convex and almost carinate in the middle, with entire, rounded anterior border. Antennae with long scapes, which reach well beyond the posterior corners of the head; first funicular joint globular, as broad as long, joints 2–7 a little broader than long, remaining joints longer. Thorax robust but not much broader than the head through the eyes. Mesonotum convex in front, slightly overarching the pronotum; scutellum not convex; epinotum rounded, sloping, without distinct base and declivity. Petiole with erect node, which is rather thick though compressed anteroposteriorly, with a blunt, rounded, entire border. Its anterior face in profile is slightly convex, its posterior face more flattened. Gaster rather short and stout; external genital valves large, with broad, bluntly bidentate tips; inner valves shorter, unciform. Wings rather large, like those of *Acropyga* with one cubital cell, no discoidal cell and the radial cell closed.

"Body shining throughout and very finely shagreened. Hairs

EXPLANATION OF PLATE

FIGURE 1. *Acropyga* (*Rhizomyrma*) *guianensis*, sp. nov. Worker head. 2. *Rh. urichi*, sp. nov. Worker head. 3. *Rh. urichi*, sp. nov. Male head. 4. *Rh. rutgersi* Bünzli. Female head of B. Guiana Colony 340. 5. *Rh. quadriceps*, sp. nov. Worker head. 6. *Rh. fuhrmanni* Forel. Mature larva with two of its hairs enlarged at left. 7. *Rh. trinitatis*, sp. nov. Worker mandible. 8. *Rh. trinitatis*, sp. nov. Worker thorax in side view, Cotype. 9. *Rh. donisthorpei*, sp. nov. Worker thorax in side view. 10. Sketch of Coccid tended by *Rh. berwicki* Wheeler type colony. 11. *Rh. fuhrmanni* Forel. Egg from Colombia Colony 996. 12. *Rh. kathrynae*, sp. nov. Worker antenna. 13. *Rh. mesonotalis*, sp. nov. Worker thorax in side view. 14. *Rh. göldii* Forel. B. Guiana Colony 576, worker thorax in side view. 15. *Rh. paludis*, sp. nov. Worker head. 16. *Rh. oko*, sp. nov. Worker head. 17. *Rh. trinitatis*, sp. nov. Worker antenna. 18. *Rh. trinitatis*, sp. nov.? Worker thorax and petiole in side view. 19. *Rh. trinitatis*, sp. nov.? Abnormal worker mandibles and clypeus. 20. *Rh. donisthorpei*, sp. nov. Worker head, B. Guiana Colony 474. 21. *Rh. donisthorpei*, sp. nov. Worker head, B. Guiana Colony 357. 22. *Rh. berwicki* Wheeler. Genitalia of male type colony. 23. *Rh. rutgersi* Bunzli. Petiole of female of B. Guiana Colony 340. 24. *Rh. panamensis*, sp. nov. Worker head.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pale, erect, absent on the thorax and anterodorsal portion of the gaster, conspicuous on the petiole, venter and genitalia. Pubescence whitish, fine and rather dense, but not concealing the shining surface. Yellow throughout; appendages scarcely paler; only the ocellar triangle blackish or fuscous. In some specimens the body is very slightly tinged with brown. Wings yellowish gray, with colorless veins and stigma." (Wheeler and Mann).

Type Locality.—San Francisco Mts., San Domingo.

Acropyga (Rhizomyrma) parvidens Wheeler and Mann

1914. *Rhizomyrma parvidens* Wheeler and Mann, Bull. Amer. Mus. Nat. Hist., 33: 46–47 (worker).
1925. *Acropyga* (*Rhizomyrma*) *parvidens* Emery, Genera Insectorum, Fasc. 183, p. 30 (worker).
1935. *Acropyga* (*Rhizomyrma*) *parvidens* Wheeler, Jour. New York Ent. Soc., 42: 327, 328 (worker).
1936. *Acropyga* (*Rhizomyrma*) *parvidens* Donisthorpe, Entomologist, 69: 110 (worker).

Worker.—"Length 1.8–2 mm. Head subrectangular, a little broader than long, as broad in front as behind, with straight sides and a slight angular excision in the middle of the posterior border. Eyes minute, consisting of about 4 small ommatidia, situated at the anterior third of the head. Mandibles oblique but with distinct basal and apical borders, the latter with 4 small subequal teeth, much smaller than in any of the known species of the genus. Clypeus short and convex, with the anterior border entire, straight and transverse in the middle. Frontal area distinct, triangular; frontal and occipital grooves distinct. Antennae 10-jointed; scapes reaching to the posterior corners of the head; first funicular joint longer than broad, second joint small, as long as broad; joints 3–5 much broader than long, joints 7–8 as long as broad, terminal joint as long as the 3 preceding joints together. Thorax shaped much as in *R. göldii* Forel, but shorter and stouter, at least behind, where it is as broad as in front; seen from above the sides are rather concave in the middle; pronotum much broader than long, with less convex humeri than in *göldii*, mesonotum not longer than broad, as it is in *göldii*, fitting into the semicircular excavation of the posterior portion of the pronotum, convex and rising above the latter in profile, abruptly sloping behind to the meso-ēpinotal constriction which is pronounced but very short. Epinotum distinctly broader than long, in profile lower than the mesonotum, with rather straight base and declivity meeting at a rounded, obtuse angle, the base distinctly longer than the declivity. Petiole with an erect, well-developed scale, which is a little more than half as broad as the epinotum, but not as high, compressed anteroposteriorly, with flattened anterior and posterior surfaces and rather blunt, entire, broadly rounded superior border. Gaster rather large, elliptical. Legs stout.

"Body shining, finely shagreened and sparsely punctate. Mandibles and clypeus somewhat more opaque.

"Hairs and pubescence whitish or pale yellow, the former rather long, unequal, erect and confined to the body, the latter rather dense

and short, covering both body and appendages, but not obscuring the shining surface.

"Pale brownish yellow throughout; legs and antennae a little paler, head in some specimens a little darker, only the eyes and mandibular teeth brown." (Wheeler and Mann).

Type Localities.—Petionville and Diquini, Haiti.

Acropyga (Rhizomyrma) marshalli Crawley

1921. *Acropyga* (*Rhizomyrma*) *marshalli* Crawley, Ann. Mag. Nat. Hist., 7: 93–95, fig. 2 (worker).
1925. *Acropyga* (*Rhizomyrma*) *marshalli* Emery, Genera Insectorum, Fasc. 183, p. 30 (worker).
1935. *Acropyga* (*Rhizomyrma*) *marshalli* Wheeler, Jour. New York Ent. Soc., 43: 327 (worker).
1936. *Acropyga* (*Rhizomyrma*) *marshalli* Donisthorpe, Entomologist, 69: 110 (worker).

Worker.—Length 2 mm. Head, excluding mandibles, 1.2 times broader than long (according to figure), sides diverging anteriorly, occipital margin feebly impressed, anterior clypeal margin convex, feebly sinuate; eyes of 2–4 minute facets at anterior third of head; mandibles 3-toothed; antennae 10–11 segmented, the second funicular segment being only partly divided, scapes attaining occipital margin, funicular segments 3–7 broader than long, 8–9 barely broader than long; terminal segment equaling the 4 preceding taken together. Thorax broader than long, epinotum broader than long, in profile as high as mesonotum, the base rounded, the declivity feebly concave. Petiolar scale viewed from in front flat, straight along the top, sides diverging slightly, becoming broadest in middle of sides. Legs short and stout. Head subopaque, finely shagreened, thorax and gaster similarly shagreened but more shining. Head, antennae, legs and gaster covered with a fairly dense whitish pubescence; sparse long hairs on clypeus, posterior portion of pronotum and shorter hairs on mesonotum, base of mesonotum and margins of gastric segments. Pale yellow, some specimens slightly darker. (Crawley).

Type Locality.—Barbados, B. W. I. (J. R. Bovell No. 346).

Recorded in soil around a sugar cane root.

Acropyga (Rhizomyrma) wheeleri Mann

1922. *Acropyga* (*Rhizomyrma*) *wheeleri* Mann, Proc. U. S. Nat. Mus., 61: 52–53 (worker, female).
1925. *Acropyga* (*Rhizomyrma*) *wheeleri* Emery, Genera Insectorum, Fasc. 183, p. 30 (worker, female).
1935. *Acropyga* (*Rhizomyrma*) *wheeleri* Wheeler, Journ. New York Ent. Soc., 43: 327–328 (worker, female).
1936. *Acropyga* (*Rhizomyrma*) *wheeleri* Donisthorpe, Entomologist, 69: 110 (worker, female).

Worker.—Length 1.5 mm. Head subrectangular, a little longer than broad, occipital margin shallowly excised; mandibles 3-toothed, basal and apical borders distinct; eyes of one facet; antennae 9-segmented, scapes attaining occipital border, first funicular segment as long as second and third taken together, segments 2–5 strongly transverse, segments 6–7 about as long as broad, terminal segment nearly as long as the three preceding segments taken together. Pro-

notum broader than long, mesonotum longer than broad and about as long as pronotum. Base of pronotum more than twice as broad as long at middle, rounding gradually into declivous surface. Petiolar scale flattened, dorsal border rounded. Shining, hairs very fine, short and abundant on head, longer and sparser on body. Pale brownish yellow with brown mandibular teeth. (Mann).

Female.—Length 2 mm. Head shorter than in worker, second funicular segment longer than broad and segments 4–5 less transverse than in worker. Petiolar scale rather thick in profile. (Mann).

Type Locality.—Lombardia, Honduras.

Workers and a female (No. 1142) which I took on Barro Colorado Island, Panama Canal Zone, August 13, 1938, agree well with Dr. Mann's description except in larger size and with longer funicular segments. Both castes have 3-toothed mandibles and 9-segmented antennae; one worker has 8-segmented antennae on one side and 9-segmented on the opposite side.

The ants were taken in soil chambers around a nest of *Sericomyrmex amabilis* Wheeler. Both nests were in Quadrate 1 of the *Anacardium* tree being studied by Doctors Park, Voth and Williams, at a distance of 60 cm. from the base of the tree in luxuriant rain forest. Unfortunately there was time for no other observations.

Acropyga (Rhizomyrma) pickeli Borgmeier

1927. *Acropyga* (*Rhizomyrma*) *pickeli* Borgmeier, Bol. Mus. Nac. Rio de Janeiro, 3:287 (worker) (not seen).
1927. *Acropyga* (*Rhizomyrma*) *pickeli* Pickel, Chacaras E Quintaes, 36: 592 (worker).
1927. *Acropyga* (*Rhizomyrma*) *pickeli* Pickel, *Rhizoecus Lendea*, n. sp., Imprensa Industrial, Recife, p. 27 (worker).
1928. *Acropyga* (*Rhizomyrma*) *pickeli* Costa Lima, Relatorio Sobre A Doença Dos Cafeeiro Em Pernambuco. Imprensa Official, Rio de Janeiro. p. 23.
1931. *Acropyga* (*Rhizomyrma*) *pickeli* Borgmeier, Rev. Ent., 1: 105–6 (worker).
1931. *Acropyga* (*Rhizomyrma*) *pickeli* Costa Lima, Bol. Biol., Fasc. 17, pp. 2–7, figs. 2–10, 12 (worker, female wing).
1932. *Acropyga* (*Rhizomyrma*) *pickeli* Costa Lima, Bol. Biol., Fasc. 21, pp. 65–69 (worker).
1933. *Acropyga* (*Rhizomyrma*) *pickeli* Borgmeier, Rev. Ent., 3: 263 (worker, female and male wing).
1935. *Acropyga* (*Rhizomyrma*) *pickeli* Wheeler, Jour. New York Ent. Soc., 43: 322–9 (worker, female, male).
1936. *Acropyga* (*Rhizomyrma*) *pickeli* Costa Lima, Terceiro Catalogo Dos Insectos Que Vivem Nas Plantas Do Brazil, Rio de Janeiro, p. 182 (worker).
1936. *Acropyga* (*Rhizomyrma*) *pickeli* Donisthorpe, Entomologist, 69: 110 (worker, female, male).

Worker.—Length 2–2.2 mm. Head, excluding mandibles, broader than long, occipital margin impressed, sides convex, rounding broadly into the occiput, anterior clypeal margin truncate or feebly convex; eyes minute; mandibles 4-toothed, the basal tooth being minute; cutting margin more oblique than in *decedens*; antennae 10–11 segmented, scape distinctly not reaching occipital angles. Color yellow. (Borgmeier).

Female.—Length 2.8 mm. Head, excluding mandibles, squarish; mandibles 4-toothed; antennae 11-segmented. Pale yellow.

Male.—Length 1.3–1.6 mm., antennae 9-segmented. (Donisthorpe).

Type Localities.—Parahyba do Norte and Pernambuco, Brazil. Also known from Surinam.

This species cultivates coccids on the roots of coffee. The ants transport the coccids from place to place and excavate a labyrinth of galleries for this purpose. Winged females disseminate the coccids by carrying them on the nuptial flight. The coccids and ants are thus enabled to spread widely. For further information on these ants the works of Pickel and Costa Lima may be consulted.

Acropyga (Rhizomyrma) bruchi Santschi

1929. *Acropyga* (*Rhizomyrma*) *bruchi* Santschi, An. Soc. Cient. Argentina, 107: 38 (of reprint) (worker).
1935. *Acropyga* (*Rhizomyrma*) *bruchi* Wheeler, Jour. New York Ent. Soc., 43: 327 (worker).
1936. *Acropyga* (*Rhizomyrma*) *bruchi* Donisthorpe, Entomologist, 60: 110 (worker).

Worker.—Length about 2 mm. Head broader than long, sides straight or a little convex, occipital margin straight, anterior clypeal margin straight; eyes small, of one or two facets, situated a little in front of anterior third of sides; mandibles 3-toothed, the apical double the length of the basal tooth, teeth on a cutting margin forming an angle with the inner margin of mandibles; antennae 9-segmented, scape scarcely attaining occipital margin, second funicular segment scarcely as long as 3–5 taken together; 2 and 7 as long as broad, 3–5 about 1⅔–1½ broader than long, terminal segment a little longer than the three preceding taken together. Pronotum shorter, more convex and more "abrupt" than in *göldii*, mesonotum a little more convex, metanotum a little narrower. Petiolar scale vertical, thin, the dorsal border feebly convex, blunt. Shining, no erect hairs on thorax, very scattered on gaster, pubescence abundant. Pale yellow. (Santschi).

Type Locality.—Rosario de Santa Fe, Argentina.

This species is recorded merely as a "coccidophile."

Acropyga (Rhizomyrma) paramaribensis Borgmeier

1933. *Acropyga* (*Rhizomyrma*) *paramaribensis* Borgmeier, Rev. Ent., 3: 263 (worker, female, male).
1934. *Acropyga* (*Rhizomyrma*) *paramaribensis* Borgmeier, Arq. Inst. Biol. Veget. Rio de Janeiro, 1: 109–110, figs. 8–9, Pl. 1; figs. 1, 4, Pl. 2, figs. 1–2 (worker, female, male).
1935. *Acropyga* (*Rhizomyrma*) *paramaribensis* Bünzli, Mitteil Schweiz Ent. Ges., 16: 453–593, 51 figs. (worker, female).
1935. *Acropyga* (*Rhizomyrma*) *paramaribensis* Wheeler, Jour. New York Ent. Soc., 43: 327–8 (worker, female, male).
1936. *Acropyga* (*Rhizomyrma*) *paramaribensis* Donisthorpe, Entomologist, 69: 110 (worker, female, male).

Worker.—Length 1.8 mm. Head, excluding mandibles, approximately as broad as long, occipital margin distinctly impressed, sides subparallel, rounding broadly into occiput; eyes minute, of 3–4 facets, situated on the anterior fourth of the head; mandibles 3–4 toothed, apical the largest; antennae 7–8 segmented, scape short, extending about three-fifths the distance to the occiput, second funicular segment may be divided (in the 8-segmented form); terminal segment

longer than the preceding four taken together (in the 8-segmented form). Thorax broader anteriorly than posteriorly, in profile with slightly concave pronotum, distinct pro-mesonotal impression, moderately convex mesonotum, two impressions in the meso-epinotal region and epinotum convex with a declivous surface much longer than the basal. Petiolar node inclined forward, anterior face in profile convex, apex somewhat pointed, posterior face feebly convex.

Moderately shining, finely shagreened. Pubescence pale yellow, abundant; pilosity erect, short. Color yellow, teeth infuscated. (Borgmeier).

Female.—Length 2.5 mm. Head, excluding mandibles, slightly broader than long, occipital margin distinctly impressed, sides subparallel, anterior clypeal margin convex; eyes large, convex, situated closer to the mandibular insertions than their diameter; mandibles 3-toothed; antennae 7–9 segmented, first funicular segment a little longer than the second. Epinotum abrupt, basal face extremely short. Wing 2.5 mm. (Borgmeier).

Male.—Length 2.2 mm. Head, excluding mandibles, broader back of eyes than long, occipital margin impressed, anterior clypeal margin convex; eyes very large, convex; mandibles 3–4 toothed, the teeth large and acute; antennae 10-segmented, scape not quite attaining the occipital corners. (Borgmeier).

Type Locality.—Paramaribo, Surinam.

These ants were taken by Bünzli from the roots of Liberian coffee where they were tending the coccids previously mentioned. His observations began early in 1931 and on April 16 winged females were taken on the surface of the ground. After a series of rainy days at 9 A. M. one morning he found three winged females, each carrying a small coccid (*Rhizoecus coffeae*) between her mandibles.

In 1932 (January 16 and 26, February 4 and 8) he found females flying with coccids at heights of 3–7 meters both in the morning 8–10 A. M.) and early afternoon (2–3 P. M.).

Rhizomyrma rutgersi females which occurred in the same locality were not observed to carry coccids.

For further information on the biology of this species Bünzli's paper may be consulted.

A female of this species was taken in virgin rain forest bordering the Oko River, a short tributary of the Mazaruni River, British Guiana June 26, 1936, by myself. The ant was found in a small tunnel at the base of the turret entrance to the nest of the fungus-growing ant, *Trachymyrmex phaleratus* Wheeler. The ants nested in heavy clay soil and there was no cultivated coffee or cacao for many miles.

Acropyga (Rhizomyrma) rutgersi Bünzli

Figures 4, 23

1935. *Acropyga* (*Rhizomyrma*) *rutgersi* Bünzli, Mitteil. Schweiz Ent. Ges., 16: 453–593, 51 figs. (worker, female, male).

1936. *Acropyga* (*Rhizomyrma*) *rutgersi* Donisthorpe, Entomologist, 69: 110 (worker, female, male).

Worker.—Length 2.4–3.2 mm. Head in front view, excluding mandibles, in Bünzli's Abb. 12J and Abb. 8A is 1.1 times *broader* than

long, in his Abb. 12K it is 1.1 times *longer* than broad, anterior clypeal margin straight in Abb. 12J, feebly convex in Abb. 12K; mandibles 3–4 toothed, in Abb. 8A mandible with two teeth and a median denticle, in Abb. J-K with three distinct teeth; antennae 9–11 segmented, scape in Abb. 8A distinctly not reaching occiput and the second funicular segment is partially divided so that the antenna has 10 complete segments. (Bünzli).

Female.—Length 3.6–4.8 mm. Head in front view, excluding mandibles, in Bünzli's Abb. 8B is 1.14 times broader than long, occipital margin straight; one eye in the figure is higher than the other and both are convex; mandibles with three well developed teeth; antennae 10–11 segmented, the respective lengths of the scapes in the figure are 26.5 and 28 mm. so that the scapes either extend to the occiput or beyond it. (Bünzli).

Male.—Length 2.8–3 mm. Mandibles 3-toothed, antennae 12-segmented. (Bünzli).

Type Locality.—Paramaribo, Surinam.

If the drawings of worker heads in Bünzli's paper are accurate, the proportions of his figures J and K are those of different species. On the supposition that the figures are not all accurate I have identified a colony which I collected at Macuto, near La Guaira, Venezuela, as this species. In this colony (No. 673, August 16, 1936) the worker is 2.5–2.8 mm. long, has the head as broad as or slightly broader than long, (1.1 : 1), the anterior clypeal margin is convex, the mandibles are 3-toothed and the antennae 10-segmented. The female, 3.9 mm. long, has the head 1.1 times broader than long, the occipital margin straight, the mandibles 3-toothed and the antennae 11-segmented. The male, 2.5 mm. long, has 3-toothed mandibles and 12-segmented antennae.

Other collections, of females, made in Trinidad and British Guiana (Nos. 196.2, 255, 340) appear to be of this species though when typical specimens of *rutgersi* are available they may prove to belong to a new subspecies. They have the following characters:

No. 196.2–Rio Claro, Trinidad, 16. vi. 1935, 3.3 mm. long, head 0.62 x 0.57 mm., rest as in No. 340.

No. 255—Imperial College of Tropical Agriculture, Trinidad, 3. viii. 1935, 3.2 mm. long, head 0.65 x 0.58 mm., rest as in No. 340.

No. 340—Forest Settlement, Mazaruni R., British Guiana, 29. viii. 1935. Length 3.4 mm. (of thorax 1.0 mm.), head in front view broader than long, 0.66 x 0.59 mm., mandibles 3-toothed, antennae 11-segmented.

One more collection, of a colony (No. 286) from British Guiana (Forest Settlement, Mazaruni R., 17. viii. 1935), is evidently of *rutgersi* but may also prove to be a new subspecies unless *rutgersi* is unusually variable. These ants have the following characters:

Worker.—Length 2.2–2.8 mm. (of thorax 0.5–0.6 mm.), average 2.5 mm. Head in front view, excluding mandibles, slightly broader than long, mandibles 3-toothed; antennae 10-segmented, in one worker 9-segmented with a partially formed tenth segment, scapes extending to the occiput. Differing chiefly from the Venezuelan specimens of *R. rutgersi* (*q. v.*) in smaller size, narrower head, shorter scapes and duller, dirtier yellow color.

Female (Deälate).—Length 3.9 mm. (of thorax 1.0 mm.). Head in front view, excluding mandibles, 1.15 times broader than long; mandibles 3-toothed, antennae 11-segmented. Differing from the female of No. 340 chiefly in having a broader head and paler and duller color, the brown ocellar blotch being especially paler.

Male.—Length 2.4 mm. (of thorax 0.86 mm.). Mandibles 3-toothed, the apical being separated by a greater diastema than that between the middle and basal teeth which are also much smaller; antennae 12-segmented, the scapes exceeding the occipital corners by a third their lengths.

Biology.—The important studies of Bünzli (Bünzli, 1935) are summarized in the beginning of this paper and deal with this species and *R. paramaribensis* (*q. v.*). His paper should be consulted for the complete account. *R. rutgersi* tends coccids on the roots of Liberian coffee and Bünzli concluded that the ants are obligate coccidophiles. The swarming of this species was not observed but Bünzli was convinced that its habits were essentially similar to those of *R. paramaribensis*.

My Venezuelan specimens were taken from their nest at the base of a banana clump up the river valley ½–1 mile back of the village. The bananas grew at a point where a reservoir emptied from the side into the stream bed and produced a small, wet area in an otherwise semi-arid region. The soil was an alluvium of sandy clay, gray-brown in color. The *Rhizomyrma* nest was in small chambers in the soil about a nest of the fungus-growing ant, *Acromyrmex octospinosus* Reich. In a blind pocket several centimeters beneath the surface about a dozen tiny coccids, unlike the common Trinidad form in habitus, and two or three large, plump coccids were found with ants. Coccids were also pastured on roots leading to the banana clump. The coccids were carried by the ants grasping them in the middle of the body, long axis parallel with that of the ants, but not always with the dorsal side uppermost. The coccids folded their legs when being transported. Ant eggs and coccids occurred in several chambers. Many winged females and males were in several chambers and one male took flight, indicating that he was mature. The soil 1–6 cm. down was permeated by the ant tunnels. No cacao was noticed in this area but there were in the vicinity what may have been young coffee plants.

The Guiana females (No. 340) were taken as they flew west just before and after sunset around 6 P. M. from the direction of a savannah area bordering the Mazaruni River towards the high rain forest a few rods from where I captured them. On this morning as well as on the previous day it had been raining heavily. The evening, however, was clear and calm. The ants pursued a steady course 5 to 7 feet above the ground and it was at once apparent that each was carrying a gleaming white object in her jaws. Upon capture each was found to be carrying a plump coccid by grasping the dorsum just back of the carapace and between the legs of the ants. The females flew near zigzagging swarms of small male ants of this species but were not seen to enter these swarms. They may have mated earlier.

The female taken near Rio Claro, Trinidad, flew into our touring car as we passed through heavy rain forest in the late afternoon. It, too, was carrying a plump coccid in its jaws.

Only one female was seen at St. Augustine, Trinidad, but this was flying close to one of a number of swarms of male *Rhizomyrma* which may well be of this species. In the twilight and just preceding the setting of the sun (6–6:30 P. M.) fully a dozen swarms of the males were zigzagging at a height above ground of six inches to five feet. The swarms were dense, approximately columnar in form, one to several feet high and six inches to one foot in diameter. The solitary female flew a few feet from one of the swarms and was easily distinguished by her much larger size and bright yellow color. The males were small and dark with 3-toothed mandibles and 12-segmented antennae.

The Guiana colony (No. 286) was discovered hardly a mile east of the place where the Guiana females (No. 340) were flying and the latter seemed to have come directly from the more easterly locality. The colony was a few rods from the Mazaruni River in a grassy savannah and was found 10 cm. beneath the entrance to a nest of *Atta sexdens* ssp. *rubropilosa* Forel in yellowish sand. Colonies of *Cyphomyrmex rimosus*, *Holcoponera*, *Pheidole* and other ants likewise occurred nearby in the sand heaped up by the *Atta* or in soil about the fungus gardens. No coccids were found with the few scattered *Rhizomyrma* workers taken this day, August 17. August 31 the site was revisited and after diligent searching in the yellowish sand in the same spot additional workers, two dealate females, males, brood and coccids were taken about the roots of grass (later determined by Miss Chase of the U. S. Dept. Agriculture as *Axonopus compressus* (Swartz) Beauv.). Brood and coccids were taken at depths of 6–15 cm. on the small roots or in chambers. Most of the coccids were in blind pockets with the brood but away from the roots. Some coccids, however, were taken directly on the roots. A black *Pheidole* worker carried off a live *Rhizomyrma* worker while other *Pheidole* carried *Rhizomyrma* brood.

Axonopus compressus is an important forage grass in the tropics. No damage from the ant-coccid association was obvious here, however, for the grass grew luxuriantly.

If *R. rutgersi* and its coccids are not confined to coffee roots the problem of control is made much more difficult, for this grass, bananas and probably numerous other plants to which these insects might be attracted are widespread.

Acropyga (Rhizomyrma) berwicki Wheeler

Figures 10, 22

1935. *Acropyga* (*Rhizomyrma*) *berwicki* Wheeler, Jour. New York Ent. Soc., 43: 321–329, fig. 1 (worker).

1936. *Acropyga* (*Rhizomyrma*) *berwicki* Donisthorpe, The Entomologist, 69: 110 (worker).

Worker.—Length 1.5–1.8 mm. "Integument thin and collapsible. Head as long as broad, with nearly straight, parallel sides, broadly rounded posterior corners and feebly convex posterior border. Eyes minute but deeply pigmented, consisting of 6 or 7 unequal, indistinct ommatidia, situated at the anterior sixth of the sides of the head. Mandibles narrow, curved, with very oblique apical borders bearing four subequal, acute teeth, the basal tooth separated from the other three by a distinct diastema and in some specimens stouter and less

obliquely inserted. Clypeus rather short, convex in the middle, with broadly rounded anterior border. Frontal carinae small, rounded; frontal area distinct, impressed, subtriangular; frontal groove obsolete. Antennae 8-jointed; scapes not reaching the posterior border of the head by fully one-fifth of their length; first funicular joint as long as the two succeeding joints together; second joint slightly longer than broad, narrowed at the base; 3–6 distinctly broader than long, increasing gradually in size distally to the terminal joint which is swollen and somewhat longer than the three preceding together. Thorax very short, less than twice as long as broad, widest through the pronotum which is twice as broad as long, in profile rising posteriorly to the mesonotum which is small but convex, sloping posteriorly to the distinct but short meso-epinotal constriction; epinotum broader than long, broader behind than in front, in profile nearly as high as the mesonotum, with anteriorly rather abruptly convex base passing gradually into the longer, flattened, sloping declivity. Petiole short, convex ventrally, its scale erect, rather small and thin, though thicker at the base than at the superior border, which is blunt broadly rounded and much lower than the base of the epinotum. Gaster large and convex anteriorly as in the other species of the genus. Fore tarsi slightly dilated.

"Shining; mandibles smooth, with a few scattered, piligerous punctures; remainder of body very finely reticulate, or superficially shagreened.

"Pilosity and pubescence yellowish, short, erect or suberect, the former dense and abundant, especially on the head, merging with the pilosity which is much sparser and longest on the pro- and mesonotum and tip of gaster.

"Pale yellow throughout, except the mandibular teeth which are deep red or dark brown." (Wheeler).

Type Locality.—San Raphael, Trinidad, B. W. I.

The descriptions below are taken from the type colony which I visited with its discoverer, Mr. E. J. H. Berwick. Only workers were taken originally by Mr. Berwick.

Worker.—Length 1.3–1.8 mm. Antennal scapes in some are shorter than in Dr. Wheeler's figure and fail to reach the occiput by about twice their distal diameter. Basal teeth are also more reduced and the occipital impression more distinct. Of 44 workers, all had both right and left antennae 8-segmented and had 4-toothed mandibles.

Female (Undescribed).—Length 2–2.5 mm. Head in front view, excluding mandibles, slightly broader than long, sides sub-parallel, occipital margin convex; eyes large, situated closer to the mandibular insertions than their diameters; antennae 8-segmented, scapes reach a level with the posterior ocelli; mandibles 4-toothed, the basal tooth small and of variable development. Dull, densely pubescent, the hairs partly reclinate, partly upright. Head and thorax brownish yellow, remainder paler, mandibular teeth and ocellar area infuscated.

Male (Undescribed).—Length 1.4 mm., antennae of 19 males 8-segmented right and left, mandibles 4-toothed. Petiolar node from above twice as broad as long, sides convex.

May 31, 1935, a few months after my friend, Mr. Berwick, discovered the colony originally we visited the site together near San Rafael. He had discovered the workers in cylinders of soil taken from beneath cacao trees on a large cacao estate in connection with soil studies. The holes left in the soil by the removal of the cylinders were still visible and guided us to the exact site of the colony. Fifteen inches from the base of a cacao tree all castes and coccids were taken in the top inch of heavy clay soil. Females and males were in separate chambers about eight inches apart, with workers and coccids. These chambers were merely slight enlargements of the tunnels which ramified through the top inch or two of clay under a layer of cacao leaves. Coccids were found pastured on the cacao rootlets. Earthworms and other tunnelling animals were also present in the clay and were inimical to the ants in that their tunnelling activities tended to break up the ant tunnels. In places where the earthworms were abundant the ant tunnels were mostly deserted. The ants have weak mandibles and probably could not bite the earthworm cuticula to an appreciable extent.

Additional collections of this species were made in Trindidad as follows:

April 1, 1935—Basin Hill Forest Reserve (central part of island at 700 ft. above sea level). The ants occurred in second growth scrub forest called lastro and there was no cacao or coffee within hundreds of feet at the minimum or about a mile along a road. Coccids were pastured on the roots of herbs and other plants in deep shade at a depth of between one and two inches only. The workers sought to carry the coccids away. A winged female was found on my collecting kit some rods away.

May 11, 1935—Mt. St. Benedict, Northern Range, in stream flood debris under cacao.

May 12, 1935—Foothills north of Tunapuna, in tunnels immediately beneath soil surface under cacao. Soil a friable clay under humus and leaf mold. Tending coccids which "lashed" their tails in a vertical plane over their dorsal surfaces when they were disturbed.

June 18, 1935—A half mile up Tucuragua River, a tributary of the Tucarigua River, Northern Range. In rotted wood and humus under cacao.

April 28, 1935—Mason's estate just north of Arima. A colony with females, workers, brood and coccids nested in damp clay-loam alluvial soil under cacao, coffee, banana and Immortelle shade trees in a new section of the plantation. The cacao and Immortelle trees were old remnants. The ants and coccids were in small anastomosing tunnels in the upper few centimeters of soil. The coccids were in bare tunnels and probably they and the ants were "marking time" until the rains came so as to be able to get on juicy rootlets. All of the plantation was very dry except a small area adjacent to several watercourses.

The April 1st colony was collected with soil and placed in an observation nest. During the night of April 2 workers of a pest ***Monomorium*** invaded the nest and ate all the sugar syrup which was placed in the nest for the ***Rhizomyrma***. The ***Monomorium*** were exterminated. By April 5 the colony had stabilized, the ants having gathered all brood and coccids in several tunnels which they had made in the soil. The

ants were, of course, strongly photophobic and could rarely be studied to advantage. April 18 they were moved to a better nest. April 25 a number of workers, one queen and larvae were found in a piece of clay which was broken up for examination. The larvae were attached to the sides of the tunnels by their hairs. April 30 a worker, when I examined the nest, waved its antennae in my direction as though it saw me; the nest was glass-covered. May 20 the colony, upon breaking the soil up, was found to be dead. Young and adult cheese mites were moving in masses through the tunnels.

The May 12 colony was also collected and placed in an observation nest. They also tunneled into the soil. Under a binocular the colony was watched May 21. A large coccid with bifurcated "tail" excreted a clear droplet on the dorsum of the "tail" at the base of the bifurcation where there was a tuft of long hairs. It was disturbed by the light and wandered awkwardly about with the "tail" held horizontally. An ant, ignoring the droplet, finally grasped it by its dorsal surface at the "carapace" and carried it down a tunnel. All the coccids, large and small, were similarly carried away with the long axis parallel to that of the ant and head end forward.

Acropyga (Rhizomyrma) robae Donisthorpe

1936. *Acropyga* (*Rhizomyrma*) *robae* Donisthorpe, Entomologist, 69: 108–111, figs. 1–3 (worker, female, male).

Worker.—Length 2.3 mm. "Pale yellow, apex of mandibles and teeth reddish-brown, eyes brown, whole body clothed with longer and shorter, erect or sub-erect, pale yellow hairs, extremely finely and closely punctured.

"Head subrectangular, about as long as broad, sides feebly rounded, posterior border slightly emarginate; eyes very small, consisting of about three facets, situated on the sides of the head about a quarter of the length of the head from anterior border; mandibles narrow, curved, armed with three pointed teeth, the apical one being the longest; clypeus convex, rounded in front; frontal area distinct, moderate, triangular; frontal furrow not present; frontal carinae moderate, bisinuate; antennae 8-jointed; scape curved, not quite reaching the posterior corners of the head when bent back; funiculus increasing in breadth to apex, first two joints elongate, third and fourth transverse, fifth and sixth as long as broad, last joint pointed, as long as the three preceding taken together. Thorax robust, not quite as long as the head and mandible taken together; pronotum transverse, rounded at sides; mesonotum convex, higher than pronotum, suture between distinct; meso-epinotal suture somewhat deep, well defined; epinotum convex round, sloping gradually to the declivity, which is longer than the dorsal region. Petiole short, furnished with a node which is pointed above, the anterior surface flat, the posterior surface slightly concave; gaster rather long and bulky, pointed at apex. Legs moderate, not very slender." (Donisthorpe).

Female.—"Length 3.4 mm. Pale yellow, apex of mandibles and teeth reddish-brown, eyes, ocelli and a spot at insertion of fore wing black. Larger, but with structure, etc., except the usual differences,

much as in the worker. The mandibles and apical tooth are longer; eyes and ocelli well formed; wings somewhat dusky, one cubital cell, no discoidal cell, radial cell closed." (Donisthorpe).

Male.—"Length 2.3 mm. Smaller than the female, dirty brownish yellow, head blackish. Eyes large; ocelli moderate; mandibles thin, curved, with an angulation near apex (but no teeth); apical tooth pointed; antennae 10-jointed; node of petiole rather large, rounded above, anterior and posterior surfaces flat. Wings as in female." (Donisthorpe).

Type Locality.—La Esperanza, Colombia.

The colony was taken associating with a small coccid at the roots of coffee in April, 1935.

Acropyga (Rhizomyrma) borgmeieri Donisthorpe

1939. *Acropyga (Rhizomyrma) borgmeieri* Donisthorpe, Proc. Ent. Soc. London, 8: 153–4 (male).

Male.—"Length 2.2 mm. Pale brownish-yellow, head somewhat darker, legs and antennae lighter, very finely punctured, shining, clothed with decumbent pubescence, especially on the gaster, and longer and shorter, suberect hairs. Head transverse, evenly rounded from behind eyes to posterior border, posterior border very slightly sinuate in centre; clypeus transverse, convex, anterior border evenly rounded; frontal area distinct; frontal furrow shallow, reaching median ocellus; eyes large, hemispherical, projecting, occupying nearly half the side of the head; ocelli moderate; mandibles slender, arched, with three teeth to the masticatory border; antennae 12-jointed, fairly long, scapes extending a little beyond posterior angles of head, funiculus with 1st joint triangular, about as broad as long, broader than joints 2–7, which are transverse, the rest longer, last joint a little longer than the two preceding taken together. Thorax convex; mesonotum rounded anteriorly, over-reaching the pronotum; scutellum transverse, slightly convex; epinotum convex, rounded without marked declivity; petiole nodiform, with a blunt rounded point above, slightly convex anteriorly, concave posteriorly and narrowly margined; gaster with genitalia somewhat elongate; external genitalia very large and prominent, stipes long, curved and furnished with a triangular hook, volsellae short and hooked, sagittae narrow with blunt turned-up apex. Wings translucent, covered with minute hairs, pterostigma and veins pale brownish-yellow, no discoidal cell, one cubital cell and closed radial cell." (Donisthorpe).

Type Locality.—Forest Settlement, Mazaruni R., British Guiana.

Acropyga (Rhizomyrma) mesonotalis, sp. nov.

Figure 13

Worker.—Length 1.8–2.1 mm. (of thorax 0.5–0.6 mm.). Head in front view, excluding mandibles, as broad as long or very slightly broader, occipital margin distinctly impressed, sides convex and rounding broadly into the occiput, anterior clypeal margin feebly convex; eyes small, 0.03–0.04 mm. in diameter, situated on the

anterior fourth of the sides of the head; mandibles 4-toothed, the teeth situated on an oblique cutting border and progressively decreasing in size from the large, acute apical tooth; antennae 9–10 segmented, the second funicular segment being in some specimens incompletely or completely divided, scapes slightly exceeding occipital corners. Thorax in side view characterized by a high mesonotum and an almost evenly convex epinotum whose basal and declivous margins are indistinctly separated; from above the pronotum appears lunate and is much wider than the epinotum, meso-epinotal region moderately impressed, the impression involving the posterior extension of the mesonotum. Petiolar node in profile sub-vertical with almost parallel anterior and posterior margins, the former being slightly convex, apex blunt; when viewed anteriorly the apex is truncate and the sides have prominent stigmata near the apex. Gaster elongate-ovate. Legs moderately short and slender.

Shining, densely and finely punctate. Pilosity of a short, appressed and somewhat thin pubescence, the individual hairs being clearly separated from one another; longer and upright hairs are sparse and distributed over the body, scapes and legs, being of irregular lengths and most abundant on the legs and gaster apically. Brownish yellow, head darker than rest of body and mandibular teeth infuscated.

Female (Dealate).—Length 3.4 mm. (of thorax 0.8 mm.). Head in front view, excluding mandibles, distinctly broader than long, occipital margin slightly concave, sides convex and rounding broadly into the occipital margin, anterior clypeal margin faintly angular; eyes moderately large, 0.06 mm. in greatest diameter, closer than their diameters from the mandibular insertions; mandibles 4-toothed, the teeth on an oblique cutting margin and all acute, apical much the longest and the basal slightly smaller than the median two; antennae 10–11 segmented, the second funicular segment being partially divided. Thorax in side view with pronotum and mesonotum rising almost vertically together at their anterior margins, epinotum feebly convex, petiolar scale in profile thin, anterior and posterior margins nearly straight, less parallel than in the worker, apex truncate. Legs moderately short and slender.

Shining, densely and finely punctate. Pilosity and color as in worker, ocellar region with a brown blotch.

Cotypes.—Workers and a female of a colony (No. 727) with coccids which I took June 6, 1938, between Petionville and Kenscoff at an elevation of about 4500 feet in the Republic of Haiti. The coccids were tended by the ants on the roots of coffee in red clayey humus from the top of the soil to 4 cm. in depth.

Though *R. parvidens* is recorded from Petionville also, this species differs distinctly, when compared with the *parvidens* description, chiefly in having much larger teeth, the antennal scapes longer, the meso-epinotal impression longer, the epinotum more rounded in profile, the petiolar node truncate above, the body not shagreened and the pubescence thinner. This is the third species recorded from Hispaniola but the first taken with coccids.

Acropyga (Rhizomyrma) panamensis, sp. nov.

Figure 24

Worker.—Length 1.5 mm. (thorax 0.41 mm.). Head in front view, excluding mandibles, rectangular, 1.3 times longer than broad, occipital margin rounded, faintly impressed medially, sides widest apart at a level with the distal ends of antennal scapes, clypeal margin convex; eyes minute; antennae 8-segmented, short, the scapes fail to reach occipital corners by a distance equal to half their length, first funicular segment longer than 2–5 taken together, terminal segment 0.18 x 0.29 mm., compressed; mandibles stout, 4–5 toothed, the basal tooth being broad and bifurcated on the right side making that mandible 5-toothed while the left basal tooth is similarly broad at the base but with only one cusp. Thorax from above 1.8 times longer than broad, two-thirds as broad through epinotum as through pronotum, moderately compressed in the meso-epinotal region; in side view rising steeply at the pronotum to a plane dorsal surface. Petiolar scale in side view thick, blunt at apex, anterior surface convex. Gaster elongate-ovate. Legs moderately short.

Shining, densely and finely punctate. Pilosity of a moderately abundant reclinate pubescence, a few scattered longer and upright hairs, especially about mouthparts and terminal gastric segments. Pale yellow, mandibles infuscated and head more intense yellow than thorax and gaster.

Holotype.—One worker (No. 922(27)) taken by Dr. E. C. Williams, Jr., on Barro Colorado Island, Panama Canal Zone. This is the species referred to as *Rhizomyrma* n. sp. (Williams, 1941, p. 79). The ant was probably among leaves on the forest floor.

Acropyga (Rhizomyrma) quadriceps sp. nov.

Figure 5

Worker.—Length 2.7–2.9 mm. Head in front view, excluding mandibles, quadrate, very slightly broader than long, occipital margin truncate, corners rounded, sides subparallel except converging behind, occipital margin feebly convex; eyes minute; antennae 10-segmented, scapes in most specimens not quite reaching occipital angles, in several workers they barely exceed the angles; mandibles 4-toothed, the basal tooth minute, the others much larger and well developed. Thorax in side view with feebly concave anterior pronotal margin, balance of pronotum and the mesonotum forming a distinct, convex lobe; meso-epinotal impression broad, deep and distinct; basal surface of epinotum short, convex, passing gently into the much longer and slightly convex declivous surface; from above broadest through pronotum, meso-epinotal region strongly constricted above. Petiole in side view conic with thick, blunt apex and straight posterior surface, crest evenly convex. Gaster ovate. Legs of moderate length.

Integument shining, finely punctate, collapsible in thorax and gaster. Pilosity of scanty long, upright hairs, more numerous but shorter upright hairs, and a fine, appressed pubescence most abundant

on head and gaster. Yellow with a brownish cast most apparent on head, mandibular teeth infuscated.

Cotypes.—Workers of one colony (No. 74) which I took March 23, 1935, near Maracas Waterfall in the Maracas Valley, Northern Range, Trinidad, B. W. I., at an elevation of 900 ft. These ants were taken within a few rods of the spot where the cotypes of *R. kathrynae* were taken. They were, however, not under trees but were found in the clay soil of the roadway in tunnels with coccids at depths of 2.5–8 cm. There were no roots in these tunnels and it is possible that heavy rains of the morning and preceding night may have forced them to this place from the adjoining forest. There were no cacao trees for hundreds of feet.

This species, compared with *R. pickeli* cotypes, is larger and with similar teeth. The occiput, however, is not impressed, the pubescence more abundant, and the pro-mesonotal impression less marked. They are closely related.

The colony was collected and placed in a small observation nest. The next morning the entire colony was hidden in a cell in a small pile of clay in a glass container placed in the nest. Some of the smaller coccids were outside the cell on moist soil. The following morning small coccids were still outside the ant cell but most had been carried in by the ants. March 26 there was no change in the appearance except that fungus had developed on banana and papaya fruit which I placed in the nest for food. March 27 the coccids had congregated at one place in the bottom of the cell, visible through the glass from below, and were tended by the ants. The ants were highly photophobic then as before. March 29 conditions were as before until the glass container was accidentally upset and ants and coccids fell out with the clay. The workers immediately grasped the coccids and buried into the soil. The next day all were together in a cell as before. March 31 the colony was alive but several coccids were alone. Between April 1 and April 18 the members of the colony gradually died. Evidently observation nests to be successful would require living plant roots to nourish the coccids who would in turn nourish the ants.

Acropyga (Rhizomyrma) kathrynae, sp. nov.

Figure 12

Worker.—Length 1.2–1.3 mm. (of thorax 0.36–0.37 mm.). Head in front view, excluding mandibles, slightly longer than broad, 0.35 x 0.39 mm., distinctly impressed medially at occiput, sides slightly convex, anterior clypeal margin truncate; eyes small, about 0.02–0.03 mm. in diameter, situated at a distance from the mandibular insertions equal to about twice their diameters; mandibles stout, with four distinct teeth of which the basal is smallest, mandibles broadest through basal tooth; antennae 8-segmented, antennal scapes extend slightly over three-fourths the distance to the occipital corners. Thorax in side view with anterior pronotal margin concave and with convexities in pronotal-mesonotal and epinotal regions, the meso-epinotal region being slightly concave; from above the thorax is about twice as broad through the pronotum as through the basal surface of

epinotum, meso-epinotal region strongly constricted. Petiolar scale convex dorsally, in side view conic, compressed, the apex rounded. Gaster elongate-ovate with pointed apex. Legs moderately short and slender.

Integument shiny, thin and collapsible. Pilosity of scattered, irregular, upright hairs most numerous on thorax and gaster; abundant short, upright hairs chiefly on head and gaster; an appressed pubescence most abundant on head and gaster. Pale straw yellow, only the mandibular teeth infuscated.

Cotypes.—Workers of one colony (No. 76) which I took March 23, 1935, near Maracas Waterfall in the Maracas Valley, Northern Range, Trinidad, B. W. I., at an elevation of 900 ft. The ants, and several of this species taken March 19 at the same spot, were found among humus on the forest floor in a shady ravine. Growing nearby were cacao as well as other trees. This species, which is dedicated to my mother, is close to *fuhrmanni* but is smaller and with distinctly shorter antennal scapes.

Workers (Nos. 1172, 1178, 1185, 1187) which I took on Barro Colorado Island, Panama Canal Zone, agree closely with the cotypes. Several of the specimens are slightly larger (1.5 mm.) and slightly less impressed in the meso-epinotal region but all have similar head proportions, etc., and have the same pale, almost ivory, color of the thorax. They were taken on the same day, August 15, 1938. Workers were found in soil about the nest of *Cyphomyrmex costatus* Mann with its guest ant, *Megalomyrmex* (*Cepobroticus*) *wheeleri* Weber, which was under a small stone. Occupying the same runways with the *Rhizomyrma*, as well as adjacent and anastomosing chambers, were workers of a tiny yellow myrmicine. The second record was of *Rhizomyrma* workers close to a nest of *Cyphomyrmex costatus* Mann[5] but under a nearby stone. Both localities were on a rocky slope in luxuriant rain forest. The third and fourth records were both under rocks, one having tunnels anastomosing with those of a minute yellow myrmicine, the other similarly associated with a very small yellow ponerine ant.

Acropyga (Rhizomyrma) urichi, sp. nov.

Figures 2, 3

Worker.—Length 1.5–1.9 mm. (of thorax 0.4 mm.). Head in front view, excluding mandibles, 1.1 times longer than broad, occipital margin distinctly impressed, sides convex and converging broadly to occiput, anterior clypeal margin convex; eyes minute, 0.02 mm. in diameter; mandibles 4-toothed, the basal tooth small and not greatly more distant from the third than the third is from the fourth; antennae 7–8 segmented, scapes short, failing to reach the occipital angles by about twice their distal diameter. Thorax in side view with concave anterior pronotal margin, distinct pro-mesonotal impression, flat dorsal surface which forms a distinct angle with the declivous surface of the epinotum; thorax from above one and two-thirds times longer than broad, strongly compressed in the meso-epinotal region. Petiolar scale with convex anterior and largely straight posterior surface, truncate at apex. Gaster elongate-ovate. Legs moderate.

[5]A photograph of the nest and site has appeared (Weber, 1941, Pl. 2).

Shining, finely punctate. Pilosity of a fine, appressed to reclinate pubescence which is most conspicuously abundant on the thorax and legs; with upright, longer and sparse hairs of variable lengths scattered generally over the body. Pale yellow, mandibular teeth infuscated.

Female.—Length 2.2 mm. (of thorax 0.7 mm.). Head in front view, excluding mandibles, 1.1 times longer than broad, occipital margin feebly convex, sides sub-parallel, anterior clypeal margin faintly convex, nearly straight; eyes large (0.11 mm.), situated much closer to the mandibular margin than their diameters; antennae 8-segmented, scapes failing to reach occipital angles by a distance about equal to their distal diameters, funiculi short, segments 3–5 as broad or broader than long. Petiole in side view cuneate, blunt and thick at apex, from above truncate apically. Gaster elongate, cylindrical. Legs moderate.

Shining, finely punctate. Pubescence on the head short, reclinate and abundant, on the thorax longer, more upright, on the gaster, longer, reclinate and abundant; appendages with abundant, long pubescence; pilosity of scattered, long, upright hairs. Head brown, ocellar region and mandibles infuscated; thorax, appendages and petiole light yellowish brown; gastric segments becoming dark brown posteriorly.

Male.—Length 1.8 mm. (of thorax 0.5 mm.). Head in front view, including mandibles, ovate; antennae 9-segmented; mandibles with a single long, acute apical tooth and a concave cutting margin which is separated from the inner margin by an obtuse angle. Epinotum in profile convex. Petiole thick, truncate at apex, the sides rounded. Wings hyaline, iridescent, with pale brown veins. Shining, finely punctate. Pilosity of a moderately abundant reclinate pubescence and sparse, upright, long hairs. Head and thorax brown, thorax and appendages pale brown.

Cotypes.—Specimens of all castes from two colonies (Nos. 438 and 440) which contained coccids and were 265 meters apart under cacao at the La Montserrat Estate, Maracas Valley, Trinidad, B. W. I., May 27, 1936. This species, which is dedicated to the late Mr. F. W. Urich, is close to *R. berwicki* but differs especially in having a narrower head and a plane dorsal surface of the thorax. The basal tooth of the mandible is closer to the other teeth and the antennal scapes are somewhat shorter.

Biology.—Colony 438 occurred under a cacao tree and 90 cm. from its trunk. The colony was surrounded by not only cacao but also banana and coffee, the nearest banana plant being 190 cm. and the nearest coffee tree 380 cm. distant. In an area with a diameter of 10 cm. were found nests of the termite, *Anoplotermes* sp., and ants of this *Rhizomyrma*, *Prionopelta*, and *Pheidole*, all having chambers or tunnels anastomosing with one another at depths of 2.5–7.5 cm. in reddish clay soil beneath a layer of leaf mold, largely from cacao leaves. Heavily shading this area were the cacao and Immortelle trees as well as numerous vines and herbs which were mostly about 20 cm. high. This valley has an annual rainfall probably of about 80 inches.

Two queens and most of the broad and coccids found were in a chamber at a depth of 7.5 cm. which lacked any roots. The tunnels

radiating out from the chamber were penetrated by roots which likely came, at least in part, from the nearby cacao tree and which supplied the food for the coccids. The termites and other ant colonies probably had no particular relationship with the *Rhizomyrma* and merely occupied the same habitat.

Colony 440 was 45 cm. from a cacao tree of the same plantation. The males and most of the brood and coccids were in clay 1–2 cm. from the surface while the workers and brood occurred still deeper to 8 cm. 185 cm. away was a coffee tree with green fruit and 160 cm. in the opposite direction was a smaller coffee tree. Coccids were found pastured on cacao roots close to the surface.

The same cacao tree was also suffering from the attacks of membracids which were tended on the cacao pods by *Azteca* ants. The ants erected carton sheds over the membracids, generally on the protected side touching the trunk of the tree. Other membracids were freely exposed but were similarly tended by these active, vicious and exceedingly aggressive ants which emit a sticky, offensive-smelling anal fluid of a whitish color. Under one *Azteca* carton shed on the cacao pod nearest the ground a flourishing colony of *Monomorium* with brood occurred, though the *Azteca* could easily have demolished the carton. Clearly they tolerated one another.

Acropyga (Rhizomyrma) trinitatis, sp. nov.

Figures 7–8, 17–19

Worker.—Length 2–2.2 mm. (of thorax 0.64 mm.). Head, excluding mandibles, squarish, between 1.0 and 1.1 times broader than long, occipital margin faintly impressed medially, sides feebly convex and rounding broadly into occiput, anterior clypeal margin feebly convex; eyes minute, 0.02 mm. in diameter, situated posterior to a level with the posterior margin of the frontal lobes; mandibles 3-toothed, the apical tooth large and acute, the basal teeth acute but much shorter, in some specimens all teeth greatly worn down to vestiges, teeth on a cutting margin which runs into the inner margin without forming a distinct angle; antennae mostly 10-segmented, occasionally 9- or 11-segmented, the loss of a segment or the adding of a segment taking place distal to the first funicular segment. Thorax in side view with pro-mesonotal and meso-epinotal sutures distinctly impressed, the anterior pronotal margin faintly concave; thorax from above one and two-thirds times longer than broad through pronotum, moderately impressed in the meso-epinotal region. Petiolar scale in side view inclined forward, anterior margin convex, posterior margin straight, apex blunt, rounded and with the dorsal margin convex when viewed from in front. Contracted gaster short-ovate. Legs of moderate length.

Shining, faintly punctate. Pilosity of a scanty short, appressed, pubescence on the head and a few long, upright hairs on the clypeus; thorax with a sparser pubescence. Pale yellow, mandibular teeth infuscated.

Female.—Length 2.6 mm. Head in front view, excluding mandibles, 1.1 times broader than long; mandibles with three blunt teeth

of which the apical and second are closest together; antennae 11-segmented. Head with a very few hairs; gaster with a more abundant pubescence and scattered hairs most numerous posteriorly.

Cotypes.—Workers and female of a colony (No. 108) which I took April 7, 1935, between the 11th and the 11¼ mile of the Arima-Blanchisseuse Road at an elevation of 1800 feet in the Northern Range, Trinidad, B. W. I. A worker and a winged female taken at this same spot (the same several square yards) March 28, 1935, probably belong to this species although the worker lacks even the vestiges of teeth and has 9-segmented antennae. The female is 3 mm. long, has the mandibles 4-toothed and in addition indications of one or two denticles, and has the antennae 9-segmented. This species is near *R. rutgersi* but comparison with the original figures of *rutgersi* is difficult because of their variability. From Venezuelan specimens ascribed to *rutgersi* this species differs in having much smaller eyes, smaller size and duller color.

Biology.—The ants were found in an area having an annual rainfall of about 120 inches and the surrounding rain forest contained tree ferns. The April ants were taken with coccids at a depth of about 3 cm. in damp clay under grass beside the road and close to a log. Brood and adults were in small chambers. The March worker was taken under this log while the winged female was found on it. The April 7 colony was taken back to the Imperial College and placed in a small observation nest with damp clay. The next morning the ants had tunneled into a piece of wet clay and had all gathered there. The marked photophobism of the ants was noted on this and successive days. April 11 several larvae and a coccid were preserved and the female was momentarily chloroformed in order to count the teeth and antennal segments. April 12 the female was alive and active while all the ants had gathered into a small cell in soaking wet clay. April 26 the colony was transferred to a Petri dish but observations were still difficult to make and by May 20 the ants had died. Fungi sprouted in numerous places on their bodies at the sutures. Long, threadlike hyphae on some terminated in yellow spherical clusters of conidia, other and shorter hyphae terminated in white spherical clusters.

A single worker was taken in humus at the base of bromeliads in low, dripping wet cloud forest on the summit of El Tucuché, 3072 feet, the second highest peak in Trinidad.

Acropyga (Rhizomyrma) donisthorpei, sp. nov.

Figures 9, 20–21

Worker.—Length 2.1–2.4 mm. (thorax length 0.55–0.57 mm.). Head in front view, excluding mandibles, 1.1 times longer than broad, occipital margin slightly impressed medially, sides and anterior clypeal margin moderately convex; eyes minute, about 0.03 mm. in diameter, situated at a level with the frontal lobes; mandibles 4-toothed; antennae 11-segmented, scapes failing to reach occipital angles by a distance equal to less than their distal diameter. Thorax in side view with strongly convex pro-mesonotum, the pro-mesonotal suture being feebly impressed, meso-epinotal impression deep, the

epinotum rising as a short convexity; from above thorax less than twice as broad as long, less than one and one-third times broader through pronotum than through epinotum, meso-epinotal region moderately impressed. Petiolar scale in side view blunt and feebly emarginate at apex, anterior margin convex, pedicel produced ventrally as a rounded lobe. Gaster elongate-ovate, legs moderately long and slender.

Shining, finely punctate. Pilosity of an abundant, comparatively long reclinate pubescence, and sparse, scattered, long, upright hairs. Brownish yellow, mandibles and clypeal margins infuscated.

Cotypes.—Workers of one colony (No. 474) which I took on Kartabo Point, between the Cuyuni and Mazaruni Rivers, British Guiana, June 15, 1936. The workers were found in wet, rotted wood of a log lying in high rain forest. When a sack of this wood and leafy humus with twigs from the upper surface of the log was examined at camp the ants were seen tending tiny, white coccids of the common Trinidad type on bright orange roots of some herb or vine. 22½ miles west of Kartabo Point on September 8, 1935, I took a worker of this species in humus from the rain forest floor on top of a white sand ridge.

This species is near *R. decedens*, *göldii* and *rutgersi*. It has shorter scapes than *göldii* and is darker, has a longer head than *decedens* with more distinct median occipital impression, and has a more distinct meso-epinotal impression than have the above species or *rutgersi*.

Acropyga (Rhizomyrma) oko, sp. nov.

Figure 16

Worker.—Length 1.7 mm. (of thorax 0.55 mm.). Head in front view, excluding mandibles, barely longer than broad, occipital margin broadly and distinctly impressed, sides convex and rounding broadly into the occipital corners, anterior clypeal margin feebly convex; eyes comparatively large (0.04 mm. diameter), situated less than three times their diameters from the mandibular insertions; mandibles 4-toothed, the basal teeth being small and widely spaced, mandibles distinctly broadest through the basal tooth; antennae 11-segmented, scapes failing to reach occipital angles by a distance about equal to their distal diameters, first funicular segment equal in length to 2–4 taken together, 3–9 transverse. Thorax in side view with concave pronotal anterior margin, strongly convex pro-mesonotum, protuberant spiracles in meso-epinotal region, the suture being distinctly impressed, basal surface and declivous surface of epinotum forming one even convexity; from above thorax nearly 1.6 times longer than broad, about 1.3 times broader through pronotum than through epinotum, sides moderately impressed in meso-epinotal region. Petiolar scale blunt at apex and feebly emarginate. Gaster elongate-ovate. Legs moderately long and slender.

Shining, finely punctate. Pilosity of an abundant long, reclinate pubescence and sparse, scattered, upright hairs. Pale brownish yellow, head darker, mandibular margins infuscated.

Cotypes.—Several workers of one colony (No. 481) which I took beside the Oko River, tributary of the Cuyuni River, about 37 miles

by trail from Kartabo Point, British Guiana, June 19, 1936. The ants were found in clay soil about a nest of *Myrmicocrypta unidentata* Weber which was itself in soil above a large nest of *Atta cephalotes* L.

R. oko is close to *R. donisthorpei* from which it differs chiefly in smaller size, larger eyes, shorter head and paler color.

Acropyga (Rhizomyrma) guianensis sp. nov.

Figure 1

Worker.—Length 2.3 mm. (of thorax 0.6 mm.). Head in front view, excluding mandibles, 1.2 times longer than broad (0.54 x 0.46 mm.), occipital margin broadly and distinctly impressed, sides and anterior clypeal margin convex, eyes 0.04 mm. in diameter, situated at that distance above a level with the posterior margin of the frontal lobes; antennae 10-segmented, scapes distinctly exceeding occipital angles, first funicular segment as long or longer than 2–3 taken together but shorter than 2–4, second funicular segment may or may not be partially divided by a suture; mandibles stout, with four stout teeth on a cutting margin which forms an obtuse angle with the inner margin, third tooth separated by a greater diastema than the others. Thorax in side view forming with the epinotum a convexity only slightly broken by the feebly concave anterior margin of pronotum, feeble pro-mesonotal and meso-epinotal impressions, and the slight angularity of the epinotum; from above one and two-thirds times longer than broad through pronotum, slightly impressed in meso-epinotal region. Petiolar node in profile thick and blunt at apex, anterior margin distinctly convex, posterior margin plane, truncate dorsally. Gaster elongate-ovate. Legs moderately long and slender.

Shining, finely punctate. Pilosity of an abundant reclinate pubescence which is somewhat scanty on the thorax, and long, upright hairs most numerous on thorax and gaster. Brownish yellow, mandibular teeth infuscated.

Cotypes.—Several workers (No. 314) which I took August 23, 1935, in virgin greenheart forest (*Ocotea Rodioei* (Schomb)) fully 4 miles north northwest of the Forest Settlement, Mazaruni River, British Guiana. This species is close to *R. göldii* but has a slightly longer head and a more distinct meso-epinotal impression. It may possibly be the worker caste of *R. borgmeieri* which is known only by the male caste.

Biology.—In a small collection of leaves and humus taken from the base of a large greenheart tree and brought back to camp, these ants were later found. In the collection were coccids which had probably been tended by these ants on the roots of herbs and trees just under the surface in pure gray sand. At the time of making the collection a single worker *Rhizomyrma* was seen here beneath a greenheart fruit which I had just overturned but it escaped. Also found in the collection was a new fungus-growing ant, *Myrmicocrypta unidentata* Weber 1937. According to the forester, Mr. T. A. W. Davis, whom I accompanied on this day, this greenheart forest may be considered a climax type. From then on, however, the composition of this locality will be changed since the Indians were just starting to cut out the smaller trees to give the younger greenhearts a better chance to develop.

Acropyga (Rhizomyrma) paludis, sp. nov.

Figure 15

Worker.—Length 2.4–2.8 mm., average of 9 workers 2.5 mm. (of thorax 0.6 mm.). Head in front view, excluding mandibles, 1.1 times longer than broad, occipital margin distinctly impressed medially, sides and anterior clypeal margin convex; eyes comparatively large (0.06 mm. in diameter), situated a distance about twice their diameters from the mandibular insertions; antennae 11-segmented, scapes failing to reach occipital angles by a distance less than their distal diameters, first funicular segment about equal to the next three taken together; mandibles stout, 4-toothed, the teeth stout and one worker with a denticle between the second and the third tooth of the right mandible. Thorax in side view with concave anterior pronotal margin, distinctly impressed pro-mesonotal suture, evenly convex mesonotum, broad and impressed meso-epinotal area with distinct spiracles, and convex epinotum; from above one and two-thirds times longer than broad through pronotum, meso-epinotal region slightly impressed. Petiole in side view, with convex anterior surface, blunt apex, which is emarginate above, and feebly concave posterior surface. Gaster elongate-ovate. Legs moderate.

Shining, finely punctate. Pilosity of a comparatively scanty reclinate pubescence which becomes coarser and longer posteriorly and sparse, long, upright hairs. Yellowish brown, head darker, mandibular teeth infuscated.

Male.—Length 2.7 mm. (of thorax 0.8 mm.). Head in front view, excluding mandibles, 1.1 times longer than broad back of eyes, occipital margin convex, anterior clypeal margin convex, eyes large (0.2 mm.), hemispherical, separated from the mandibular insertions by one-fifth the eye diameter; antennae 12-segmented, scapes exceeding occipital angles by over one-fifth their lengths, first funicular segment slightly shorter than next three taken together, terminal segment about as long as the three preceding taken together; mandibles stout, 3-toothed, the apical tooth large and acute, a distinct diastema between the apical and the second tooth, second and third teeth broad, blunt. Epinotum in side view with basal and declivous surfaces joined in a rounded angle. Petiole in side view cuneate with a rounded apex which from above is slightly emarginate, posterior surface feebly concave. Wings hyaline, iridescent, with pale brown veins.

Shining, finely punctate. Pilosity of a rather sparse reclinate pubescence and a few long, upright hairs. Head and antennae brown, rest of body pale yellowish brown.

Cotypes.—Workers and a male of one colony (No. 308) with coccids which I took August 21, 1935, in swamp rain forest a mile back of the Forest Settlement, Mazaruni River, British Guiana. This is in the type locality of *R. borgmeieri* but comparing with the original description of the latter the present species in the male caste differs particularly in having much longer antennal scapes, first funicular and terminal segments; a marked declivity to the epinotum and a feebly emarginate apex to the petiolar node. Comparing with my Macuto,

Venezuela, males of ***rutgersi*** the present species has a longer head, which is convex instead of concave on the occipital margin medially, and is much darker. A direct comparison of the male with a ***dubitata*** cotype showed distinct differences. The worker is near ***göldii*** and ***decedens*** but has larger eyes and shorter scapes than the former and with longer head and shorter scapes than the latter.

Biology.—This species was taken in true swamp rain forest miles from any cultivated coffee or cacao in what may well be the original habitat of the neotropical members of the subgenus, the vast Guianan forest between the Orinoco and Amazon Rivers. The colony nested in the hummock of decayed wood (of corkwood, *Pterocarpus officinalis*) and humus at the base of a small tree in a locality with many buttressed trees and stilt palms. Roots of lianas and aroids extended into the hummock and upon these the ants were pasturing coccids. During midday patches of sunlight would fall upon the hummock. During most of the year this hummock would be surrounded by water. On this day, at the onset of the dry season, it was surrounded by muck and some water so as to be in effect an island. The ants were highly photophobic. Coccids and ant brood occurred in the same cavities, many of which were of carton from termites which were still working the hummock. The ants carried away the coccids by grasping them with their mandibles on the dorsal surface of the "carapace" with head end forward, the whole coccid being carried between the ant legs. Their own larvae were carried in a similar manner except that they were not particular about which end or side of the larva was uppermost.

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NOMENCLATORIAL NOTES ON CICADELLIDAE

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The following new names are proposed:

Macropsis breakeiana n. n. for *M. breakeyi* Knull (Ann. Ent. Soc. Amer., 33 (2) : 371, 1940), not *M. breakeyi* Merino, (Phil. J. Sci., 61 (3), Nov. 1936.)

Erythroneura perplexa n. n. for *E. ordinaria* Knull and Auten (Ann. Ent. Soc. Amer., 31 (4) : 651, 1938), not *E. ordinaria* Ribaut (Faune de France 31, Homoptères Auchénorhynques 1, p. 47, 1937).

Erythoneura tithide var. **nudista** n. n. for *E. tithide* var. *nudata* Ribaut (*Ibid*, p. 61), not *E. nudata* McAtee (Trans. Amer. Ent. Soc., 46 : 316–317, Aug. 26, 1920).

A CHECK LIST OF THE CULICIDAE OF THE AUSTRALIAN REGION, by FRANK H. TAYLOR. Publication No. 1, 24 pp., 1 map, 1934.

DENGUE. PART I. MEDICAL, by GEORGE F. LUMLEY. PART II. ENTOMOLOGICAL, by FRANK H. TAYLOR. Publication No. 3, 171 pp., 28 figs., 1943.

MOSQUITO INTERMEDIARY HOSTS OF DISEASES IN AUSTRALIA AND NEW GUINEA, by FRANK H. TAYLOR. Publication No. 4, 154 pp., 75 figs., 1943.

Service Publications (School of Public Health and Tropical Medicine), Department of Health, Commonwealth of Australia. Printed by AUSTRALASIAN MEDICAL PUBLISHING COMPANY, LTD., Seamer St., Glebe, New South Wales. Paper bound, 6 x 9½ inches.

Publication No. 1 is a list of 220 species of the three subfamilies Dixinae, Chaoborinae, and Culicinae known to occur in the zoogeographical area called the Australian Region. It is based upon extensive studies for many years by Mr. Taylor. Pertinent references are given for each species.

Publication No. 3 is based mainly upon published literature. It should be of particular interest right now to medical and sanitary officers who see to the health of military personnel in those parts of the world where dengue occurs.

Publication No. 4 lists and describes the various species of mosquitoes in Australia and New Guinea known to be associated with the transmission of disease, and gives practical methods of control.

Publication No. 2 in this series, which this reviewer has not seen, deals with plumbism and chronic nephritis in young people in Queensland, and methods for the estimation of lead in biological materials.—CARL E. VENARD.

THE ENTOMOLOGICAL SOCIETY OF AMERICA

PROCEEDINGS OF THE THIRTY-EIGHTH ANNUAL MEETING

Columbus, Ohio, December 7-9, 1943

The Entomological Society of America held its Thirty-eighth Annual Meeting on Tuesday, Wednesday, and Thursday, December 7–9, 1943. An interval of two years had elapsed since the preceding annual meeting due to the cancellation of the Thirty-seventh Annual Meeting (cf. Annals, 35: 114). The program was arranged jointly by the Entomological Society of America and the American Association of Economic Entomologists, which held its annual meeting at the same time and place. The general theme of the program was "Entomology and the War." Approximately half of the program centered on the subtopic "Medical Entomology in Wartime" and the other half on "Agricultural Entomology in Wartime." Personnel of the United States Army, the United States Navy, the United States Public Health Service and the Royal Canadian Army Medical Corps took a leading part in the program and discussed the importance of medical entomology in maintaining the health of the members of the armed services.

The single program for both societies was arranged by a joint committee representing the Entomological Society of America and the American Association of Economic Entomologists. The subject matter and the conditions under which the meetings were held necessitated a program of selected topics with invited speakers for each topic. This type of program was therefore substituted (for the Thirty-eighth Annual Meeting only) for the usual procedure of members presenting papers reporting on their own research.

The Annual Public Address and the Entomologists' Dinner were omitted in order to devote all the available time to the topics of the program.

The attendance was far above expectations in view of restrictions on travel and the early December dates, approximately three hundred persons being present.

The program presented at the three-day meeting follows:

Opening Session, Tuesday Morning, December 7

JOINT SESSION WITH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

In the absence of President Charles P. Alexander, the members of both Entomological Societies were called to order at 10:30 A. M. by Secretary-Treasurer Clarence E. Mickel in the Hall of Mirrors, Deshler-Wallick Hotel. Secretary Mickel announced the appointment of the following committees:

Nominating Committee—H. B. Hungerford, Chairman; C. T. Brues, William A. Riley.

Resolutions Committee—C. L. Metcalf, Chairman; David G. Hall, Josef N. Knull.

Auditing Committee—R. C. Osburn, Chairman; H. O. Deay, A. G. Ruggles.

Secretary Mickel introduced Dr. P. N. Annand, President of the American Association of Economic Entomologists, who addressed the joint session of the two Societies on "The War and the Future of Entomology."

Second Session, Tuesday Afternoon, December 7

JOINT SESSION WITH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

The session was called to order at 1:00 P. M. by Secretary Clarence E. Mickel. The following program was presented:

MEDICAL ENTOMOLOGY IN WARTIME

F. C. Bishopp, Bureau of Entomology and Plant Quarantine, *Discussion Leader*

Relation of Insects to the Health of Military Personnel.
Maj. O. R. McCoy, Office of the Surgeon General, War Department.

Entomologists and the Sanitary Corps.
Col. W. A. Hardenburgh, Office of Sanitary Engineers, War Department.
Read by Major Alden E. Stilson, Sn. C., Assistant Chief, Medical Branch, 5th Service Command, Ft. Hayes, Ohio.

Insect Control at Army Training Camps in the United States.
Maj. Stanley J. Carpenter, Army Sanitary Corps.

The Malaria Control in War Areas Program of the United States Public Health Service.
S. B. Freeborn, Senior Surgeon (R), United States Public Health Service, Atlanta, Georgia.

Entomological Services on the Program for Malaria Control in War Areas of the United States Public Health Service.
G. H. Bradley, Senior Entomologist (R), United States Public Health Service, Atlanta, Georgia.

Problems of Medical Entomology of Military Importance in Canada.
Maj. R. H. Ozburn, Royal Canadian Army Medical Corps.

Mosquito Problems in the American Tropics.
Mr. W. H. W. Komp, United States Public Health Service.

Third Session, Wednesday Morning, December 8

JOINT SESSION WITH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

The Session was called to order at 9:30 A. M. by Dr. C. L. Metcalf. The topic "Medical Entomology in Wartime" was continued and the following papers presented:

Chemical Control of Insects That Affect Man's Health and Comfort.

Fumigation.
Randall Latta, Bureau of Entomology and Plant Quarantine. (10 min.).

Repellents, contact insecticides and larvicides.
E. F. Knipling, Bureau of Entomology and Plant Quarantine, and T. C. Allen, University of Wisconsin. (20 min.).

Aerosols.
L. D. Goodhue, Bureau of Entomology and Plant Quarantine. (10 min.).

Fourth Session, Wednesday Afternoon, December 8

JOINT SESSION WITH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

The Session was called to order at 1:00 P. M. by Dr. P. N. Annand, President of the American Association of Economic Entomologists, and the following papers were presented:

AGRICULTURAL ENTOMOLOGY IN WARTIME

J. J. DAVIS, Purdue University, *Discussion Leader*

The Insecticide Situation.
L. S. HITCHNER, Executive Secretary, Agricultural Insecticide and Fungicide Association. (15 min.).

The Distribution of Allocated Insecticides.
C. C. HAMILTON, War Food Administration. (10 min.).

Insect Surveys and the Distribution of Insecticides.
S. A. ROHWER, Bureau of Entomology and Plant Quarantine. (10 min.).

The Effect of Shortages of Rotenone and Pyrethrum on Crop Protection and Production.
C. E. PALM, Cornell University. (10 min.).

Substitute Agricultural Crop Insecticides.
N. F. HOWARD, Bureau of Entomology and Plant Quarantine, and T. ROY HANSBERRY, Cornell University. (20 min.).

Farm Stock Insecticides.
W. E. DOVE, Bureau of Entomology and Plant Quarantine, and J. MUNRO, North Dakota Agricultural Experiment Station. (20 min.).

Fifth Session, Thursday Morning, December 9

JOINT SESSION WITH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

The Session was called to order at 9:30 A. M. by Dr. P. N. Annand. The topic "Agricultural Entomology in Wartime" was continued and the following papers were presented:

New Agricultural Crop Insecticides.
H. L. HALLER and E. R. MCGOVRAN, Bureau of Entomology and Plant Quarantine. (20 min.).

Protection of Dried Packaged Foodstuffs for Military Usages from Insect Damage.
E. O. ESSIG, University of California, and B. N. SMALLMAN, Grain Research Laboratory, Winnipeg, Canada. (30 min.).

Protection of Stored and Dried Processed Foods and Seed Supplies from Insect Damage.
R. T. COTTON, Bureau of Entomology and Plant Quarantine. (30 min.).

Insect Problems of Seed Production.
L. G. SMITH, Washington State College, and JOHN H. HUGHES, University of Minnesota. (20 min.).

Sixth Session, Thursday Afternoon, December 9

JOINT SESSION WITH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

The Session was called to order at 1:00 P. M. by Dr. P. N. Annand. The topic "Agricultural Entomology in Wartime" was continued and the following papers were presented:

Bees and Seed Production.
J. I. HAMBLETON, Bureau of Entomology and Plant Quarantine. (15 min.).

Pest Control Industry and the War.
WM. O. BUETTNER, Secretary, National Pest Control Association. (15 min.).

Entomological Problems of the Victory Gardner.
T. H. PARKS, Ohio State University. (15 min.).

The Influence of the War on Plant Quarantines.
E. R. SASSCER, Bureau of Entomology and Plant Quarantine. (15 min.).

Extension Entomology Activities and Food and Fiber Production Programs.
M. P. JONES, Extension Entomologist, War Food Administration. (15 min.).

The Manpower Problem in Entomology.
ERNEST N. CORY, State Entomologist, University of Maryland. (10 min.).

The following is a report of the Annual Business Meeting which was held Wednesday evening, December 8, in the Deshler-Wallick Hotel. In the absence of President Charles P. Alexander, the Presiding Officer was Dr. Clarence H. Kennedy, Managing Editor of the Annals.

REPORT OF THE SECRETARY

During the year 1943, the following having been duly nominated and recommended, were elected members of the Society by mail ballot of the Executive Committee:

RALPH C. BARNES, P. O. Box 210, Jacksonville, Florida.
CAPTAIN LEWIS BERNER, A.P.O. 625, c/o Postmaster, Miami, Florida.
EDWARD MCCALLUM CALLAN, Imperial College of Tropical Agriculture, Trinidad, B. W. I.
JOHN F. CURRY, P. O. Box 401, c/o California Department of Agriculture, San Pedro, California.
HENRY S. DYBAS, Division of Insects, Field Museum of Natural History, Chicago, Illinois.
MAJOR MARSHALL HERTIG, Sn. C., Army Medical School, Washington, D. C.
ANITA HOFFMANN, Apartado 8026, Mexico, D. F., Mexico.
1ST LT. WAYNE L. HOWE, Army Medical School, Washington, D. C.
GEORGE LELAND MCCALL, Department of Entomology, Dupont Experimental Station, Wilmington, Delaware.
BARTHOLOMEW A. MAINA, 10623 Church St., Chicago, Illinois.
SEATON CRAWFORD MENDALL, New York Agricultural Experiment Station, Geneva, New York.
CHARLES L. REMINGTON, Principia College, Elsah, Illinois.

With approval of the Executive Committee a contribution of $50.00 was made to the Union of American Biological Societies to aid in publishing a pamphlet regarding the organization of graduate work in the biological sciences for distribution to Institutes and Laboratories in Latin America. Half of the total amount contributed was donated by the Second Vice-President of the Society.

The Executive Committee voted in June, 1943, its approval of the exploration of the possibility of holding an Annual Meeting in 1943.

PRESIDENT CHARLES P. ALEXANDER appointed MR. C. F. W. MUESEBECK and DR. R. E. SNODGRASS to represent the Society with power to act, at a meeting of entomologists held in Washington, D. C., June 29, 1943, to consider the possibilities of holding a joint meeting of the Entomological Society of America and the American Association of Economic Entomologists some time during 1943. The decision reached at this conference was to schedule such a joint meeting at Columbus, Ohio, on December 7–9, 1943.

With the approval of PRESIDENT CHARLES P. ALEXANDER, MR. C. F. W. MUESEBECK and MR. CURTIS P. CLAUSEN represented the Secretary on the program committee for the joint meeting at Columbus.

The Secretary attended a Conference of the Secretaries of the American Association for the Advancement of Science and affiliated societies at Chicago, Illinois, on October 2, 1943. The agenda of this conference were concerned with

plans and policies regarding the holding of meetings of the American Association for the Advancement of Science during the war period.

PRESIDENT CHARLES P. ALEXANDER reappointed the Nominating Committee of 1942 to serve for 1943, viz.: H. B. HUNGERFORD, Chairman; WILLIAM A. RILEY and C. T. BRUES.

PRESIDENT ALEXANDER appointed the following members as representatives of the Society on the Local Committee for Arrangements for the Columbus Meeting, the same persons also representing the American Association of Economic Entomologists: T. H. PARKS, Chairman; NEALE F. HOWARD and D. M. DELONG.

PRESIDENT CHARLES P. ALEXANDER appointed DR. E. O. ESSIG as the representative of the Society to the Division of Biology and Agriculture of the National Research Council for the three year term 1943–1946.

DR. S. A. GRAHAM was continued as the Society's representative on the Committee for Coordination of Entomology with the War Effort.

The Executive Committee met at 7:30 P. M., December 7, 1943, at the Deshler-Wallick Hotel, Columbus, Ohio, the following officers being present: CLARENCE H. KENNEDY and CLARENCE E. MICKEL; one other member of the committee was present: C. F. W. MUESEBECK. The following alternates designated by the President and by the Secretary-Treasurer acting for the President, served in place of the absent members of the committee: D. J. BORROR, T. H. FRISON, WILLIAM E. HOFFMANN, S. A. GRAHAM, Z. P. METCALF and R. C. OSBURN.

The following were elected to membership in the Society:

EDWARD WILLIAM BAKER, Laboratorio Entomologico, Apartado 3, Colonia Anahuac, D. F., Mexico.

JOHN W. BALOCK, Laboratorio Entomologico, Apartado 3, Colonia Anahuac, D. F., Mexico.

LAWRENCE KREMER CUTKOMP, Zoology Laboratory, University of Pennsylvania, Philadelphia 4, Pennsylvania.

CHARLES ARTHUR DAMBACH, Dept. Zoology and Entomology, Ohio State University, Columbus 10, Ohio.

THOMAS R. DAVIDSON, Dept. Entomology, University of Alberta, Edmonton, Alberta, Canada.

CHARLES O. ESSELBAUGH, 703 W. Nevada St., Urbana, Illinois.

ROBERT A. FLOCK, P. O. Box 1297, Phoenix, Arizona.

ST. SGT. K. GOGEL, U. S. A. A. B., A. P. O. 606, c/o Postmaster, Miami, Florida.

ROBERT EDMOND GREGG, State Teachers College, Duluth, Minnesota.

CHARLES R. HUNT, Box 62A, Dryden, Washington.

JOSEPH F. T. JODKA, Comstock Hall, Cornell University, Ithaca, New York.

ESMOND BRADLEY MARTIN, 465 East 57th St., New York 22, New York.

IBRAHIM EL MINCHAOUI, P. O. B. 763, Cairo, Egypt.

MARTIN H. MUMA, 4504 Guilford Road, College Park, Maryland.

WILLIAM H. NUSHAWG, 292 Sycamore St., East Aurora, New York.

LT. JOHN V. OSMUN, Medical Branch, Hdq. 2nd Service Command, Governors Island, New York 4, New York.

THADDEUS PARR, Box 156, Bexley Station, Columbus, Ohio.

ROBERT E. PFADT, Dept. Entomology, University of Wyoming, Laramie, Wyoming.

JOHN E. PORTER, 512 W. Nevada St., Urbana, Illinois.

WILLIAM FREDERICK RAPP, JR., New Jersey Agricultural Experiment Station, New Brunswick, New Jersey.

ROBERT E. RIEDER, Extension Entomologist and Plant Pathologist, Oregon Agricultural College, Corvallis, Oregon.

P. F. C. REED STEWART ROBERTS, 346 West 1st North, Logan, Utah.

ROY D. SHENEFELT, Zoology Dept., Washington State College, Pullman, Washington.

IRVING SIEGEL, 657 Crotona Park No., New York 57, New York.

ELEANOR H. SLIFER, Dept. Zoology, University of Iowa, Iowa City, Iowa.

SUE D. SPARKS, North Carolina State College, Raleigh, North Carolina.

CARL ERNEST VENARD, Dept. Zoology and Entomology, Ohio State University, Columbus 10, Ohio.

ROBERT M. YERGASON, 50 Farmington Ave., Hartford, Connecticut.

The following have resigned during the year: A. W. BAKER, E. W. BERGER, RODNEY CECIL, EDWARD H. COE, WILEY W. CRAWFORD, LYLE H. EDELBLUTE, J. A. ELSON, LYLE E. HAGMANN, ELLIS C. KENT, CHARLES G. LINCOLN, RAYMOND E. LOWRIE, H. C. MANIS, JOSEPH B. MOORE, ANN H. MORGAN, J. B. PARKER, HAL B. PARKS, H. B. PARKS, RICHARD L. POST, DWIGHT POWELL, GORDON E. SMITH, GORDON F. SMITH, HERMAN T. SPIETH, MRS. JAMES M. SPRAGUE, PETER C. TING, DOROTHYDEAN VIETS and CHARLES S. WILSON.

The following have been automatically dropped from membership either because of failure for three or more years to pay dues or because they cannot be reached: VIRGIL N. ARGO, CHARLES CURTISS, TRABER N. DOBBINS, E. MELVILLE DUPORTE, RUTH H. MADDEN, WILLIAM D. SARGENT and ALFRED ZIMMERN.

The Executive Committee elected the following Fellows: SHERMAN C. BISHOP, M. W. BOESEL, DONALD J. BORROR, E. P. BREAKEY, ELIZABETH B. BRYANT, MABEL COLCORD, ARTHUR C. COLE, JR., RALPH H. DAVIDSON, DONALD G. DENNING, HENRY DIETRICH, J. E. ECKERT, GRAHAM BELL FAIRCHILD, WILLIAM J. GERHARD, NEWELL E. GOOD, J. LINSLEY GRESSITT, ASHLEY B. GURNEY, F. H. HARRIES, LYMAN S. HENDERSON, A. C. HODSON, WILLIAM R. HORSFALL, MRS. DOROTHY J. KNULL, JOSEF N. KNULL, REGINALD H. OZBURN, H. M. PARSHLEY, FRED W. POOS, A. EARL PRITCHARD, J. SPEED ROGERS, MILTON W. SANDERSON, JOHN B. SCHMITT, FLOYD F. SMITH, CHARLES S. SPOONER, E. W. STAFFORD, HARVEY L. SWEETMAN, HENRY K. TOWNES, L. D. TUTHILL and DAVID L. WRAY.

The Society has suffered the loss by death of the following eleven members and former members during the past year: E. D. BALL, M. W. BLACKMAN, R. W. DOANE, W. P. FLINT, A. H. GREER, JOHN C. HAMLIN, W. A. HOFFMAN, FRANK E. LUTZ, R. A. MUTTKOWSKI, WILMON NEWELL and ARTHUR H. ROSENFELD.[1]

ELMER DARWIN BALL, a Charter Member and Life Member of our Society and a Fellow since 1908, was born in Athens, Vermont, September 21, 1870, and died in Pasadena, California, October 5, 1943, after long illness. His early education was acquired in the public schools of Iowa, and he received the B.S. degree in 1895 and the M.S. degree in 1898 at Iowa State College. In 1907 he was granted the Ph.D. degree by Ohio State University, where he had pursued his graduate work under Professor Herbert Osborn, with whom he prepared many joint papers in his special field, leafhoppers and related families.

After early teaching experience in the common schools of Iowa, followed by one year as Assistant Principal of Albion Seminary in 1894–95, Dr. Ball began his scientific teaching career as assistant in zoology and entomology (1895–97) at Iowa State, and continued in the same capacity at Colorado Agricultural College from 1897 to 1901. In 1902 he became Professor of Zoology and Entomology in the Utah Agricultural College, serving in this capacity until 1907. From 1918 to 1921 he was professor of Zoology and Entomology in Iowa State College, and from 1931 until his death was Professor of Zoology in the University of Arizona, though on extended leave from the latter institution since February, 1938, when he suffered a cerebral hemorrhage which left him physically incapacitated for work.

The apparent interruptions in the continuity of his teaching career resulted from calls to special scientific and administrative services as follows: from 1907 to 1916 he was Dean of the Utah Agricultural College and Director of the Experiment Station, and from 1916 to 1918 was State Entomologist of Wisconsin, where he organized the movement for eradication of American foul brood. In 1920 and 1921 he was on leave from Iowa State College as Assistant Secretary of Agriculture, under Secretaries Meredith and Wallace; and from 1921 to 1925 was Director of Scientific Work in the U. S. Department of Agriculture. Here he backed legislation raising salaries of scientific workers in the Department, enabling it to obtain and retain better research men. From 1925 to 1928 he was in charge of celery insect investigations for the Florida State Plant Board.

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[1]Information has just been received that 1ST LT. WILLIAM ROY WEST, a member of our Society since 1941, was killed in action during the invasion of the Marshall Islands on January 31, 1944. As far as is known, LT. WEST is the first member of our Society to give his life during this war. He was a 1st Lieutenant in the Marine Corps. He was a graduate of the University of Alabama and was a graduate assistant in the Department of Zoology and Entomology of Mississippi State College when he enlisted in the Marines in the summer of 1942.

In the fall of 1928 Dr. Ball became Dean of the College of Agriculture, and Director of the Agricultural Experiment Station of the University of Arizona, which positions he held until 1931, when he transferred to the Department of Entomology and Economic Zoology as Professor of Zoology and Entomologist of the Experiment Station.

Dr. Ball was an indefatigable investigator. He pioneered in the driving spray method of codling moth control, in methods of eradication of American foul brood, and in discovering the role of insects in the transmission of plant diseases. He first pointed out the causal relationship of leafhopper infestation of sugar beets to curly top disease of that crop; and later repeated this achievement on tip burn of potatoes—the third plant disease proved to be insect borne. He put every possible hour into collecting and taxonomic study of Jassidae, Cercopidae, Fulgoridae, and especially Membracidae.

His published contributions number about two hundred, of which over one hundred are taxonomic, more than sixty economic, and the remainder in the general field of science and administration. The latest catalog of Membracidae credits Ball with descriptions of 385 of the 1,525 known North American species of leafhoppers. In this connection he was the possessor of a rather notable scientific library; and of an outstanding private collection of the insect groups named, which was recently acquired by the National Museum.

Dr. Ball was a Fellow of the American Association for the Advancement of Science, and held membership in the following organizations: Association of Economic Entomologists (Past President); Pacific Slope Association of Economic Entomologists (Past President); Ecological Society of America; Washington Entomological Society; Washington Biological Society; Iowa Academy of Science; Utah Academy of Science (Past President); Ohio Academy of Science; California Academy of Sciences; Washington Academy of Science; and was one-time National President of the honorary society in agriculture, Gamma Sigma Delta; he was also a member of Sigma Xi and Phi Kappa Phi.

Dr. Ball was an enthusiastic teacher, helpful with counsel and financial assistance to worthy students. While he may have acquired some reputation for pugnacity in defense of his views (for he was not one to compromise), he was at all times courteous and helpful to inquiring constituents, and a most loyal friend.

In 1899 he married Mildred R. Norvell, who survives him.—CHARLES T. VORHIES.

MAULSBY W. BLACKMAN, a member of our Society since 1913 and a Fellow since 1937, died at his home in Silver Spring, Maryland, near Washington, D. C., on October 12, 1943. He was born at Lawrence, Kansas, March 26, 1876. He graduated from Kansas University in 1901, and received his Ph.D. degree at Harvard in 1905. As a teacher he was successively attached to the University of Kansas, Western Reserve University, and Syracuse University. At Syracuse he helped organize a department of entomology which placed special emphasis on forest insects, and he served as professor of entomology at this institution from 1913 to 1929. In 1929 he was appointed specialist in Scolytidae, with the rank of senior entomologist, in the Division of Forest Insect Investigations of the U. S. Bureau of Entomology, and in 1937 he joined the staff of the Division of Insect Identification of the same Bureau. Dr. Blackman's early work was chiefly on spermatogenesis in Chilopoda, but he is best known for his later studies on the biology, control, and classification of bark beetles of the family Scolytidae. Most of his papers published after 1920 deal with the classification of various species and genera of Scolytidae, chiefly of the North American fauna. His 1928 revision of the genus *Pityophthorus* is an outstanding contribution in the field of barkbeetle taxonomy. Although in poor health during recent years he retained a kindly disposition and fine sense of humor which endeared him to his associates; and he continued to work energetically to within a few days of his death.—C. F. W. MUESEBECK.

RENNIE WILBUR DOANE, a charter member of our Society and a Fellow from 1924 to 1938, was born in Des Moines, Iowa, on March 11, 1871, and died at his home in Palo Alto, California, on December 1, 1942. In 1891 he entered Stanford University with the first freshman class where he studied under President David Starr Jordon, Professor Vernon L. Kellogg, and Professor John H. Comstock and graduated with a major in Zoology and Entomology in 1896. After a short period of graduate work under Dr. Kellogg he accepted a position at Washington

State College, Pullman, Washington, in 1896 and rose to the rank of assistant professor in 1901. In this year also he accepted a position as superintendent of the Fisheries Experimental Station at Keyport, Washington, where he investigated the propagation of the Pacific Coast oyster as a possible commercial resource. He was called to teach Zoology and Entomology at Stanford University in 1905 and remained there until his retirement in 1937. When Dr. Kellogg resigned in 1920 the Department of Entomology was incorporated into the Department of Zoology and Doane became associate professor of Zoology and nominally headed up the work in Entomology until his retirement. He made notable contributions in systematic entomology by his early work and publication on the dipterous families Tipulidae and Trypetidae and by later investigations of the Coccidae and other insect pests of the cocoanut palms in the Samoan Islands.

He became an outstanding and leading economic entomologist and for many years was entomological consultant of mining and ore-smelting companies and other private enterprises in the western states. He also contributed materially to the control of mosquitoes in the San Francisco Bay Region; to the importance of disease-bearing insects in relation to public health and agriculture, and to the development of forest and agricultural entomology in general. His books on these subjects have had wide recognition and extensive usefulness and are a reminder of his ability and industry. Among these are "Insects and Disease," Holt, 1910; "Economic Zoology and Entomology," Holt (with Kellogg), 1915; and "Common Pests," Thomas, 1931. In addition, he published at least 47 other papers.

He was an outstanding and successful teacher and he had a marked influence on the development of Entomology in the West. His wife, Elanora Cooper Doane, whom he married in 1898, and who survives him, was a great aid to him and one whose counsel and help must have been a continual source of inspiration and power. My long and often intimate acquaintance with the Doanes afforded many opportunities to learn much of the fine spirit and superb character that were the sources of their power over all who had the opportunity and privilege to come under their kindly and inspiring influence.

Professor Doane was also a member of the American Association for the Advancement of Science, American Association of Economic Entomologists, Ecological Society of America, and local entomological and zoological organizations.—E. O. Essig.

Wesley P. Flint, a member of our Society since 1908 and a Fellow since 1931, was born at Southampton, New Hampshire, on May 4, 1883, and died on June 3, 1943, at Urbana, Illinois. He spent his youth on his father's truck farm.

In 1904 he was granted a certificate for the successful completion of a two-year course in agriculture at the University of New Hampshire. He was an outstanding example of a "self-made man." With only two years of college training, he entered upon practical entomological work at the age of twenty-three years and advanced continually thereafter. In 1906 he worked for the Massachusetts Gypsy Moth Commission and in 1907 for the H. L. Frost Company on forest insects. In October, 1907, he was appointed an assistant to the Illinois State Entomologist, Dr. S. A. Forbes, Director of the Illinois State Laboratory of Natural History, and remained in the service of that organization—now the Illinois State Natural History Survey—for more than 35 years. From 1917 to 1921 his title was Assistant Entomologist for Central Illinois. In 1921 he was appointed Chief Field Entomologist. In 1930 he became Consulting Entomologist for the Agricultural Experiment Station; and in 1935 his title was changed to Chief Entomologist of the Natural History Survey (four-fifths of his time) and Entomologist of the Agricultural Experiment Station (one-fifth of his time).

His interest was always in the applied phases of agricultural entomology; and, working under the able leadership of the late Professor Stephen A. Forbes for more than 20 years and with the aid of a number of very efficient assistants, he made a number of valuable contributions to the control of agricultural insects. He was co-author of a number of bulletins and circulars dealing with the spraying and dusting of fruit trees, the control of the chinch bug, the onion maggot, stored grain insects, the European corn borer, and the status and control of many other economic farm pests in Illinois. Over the vigorous protests of a number of agriculturists, he predicted that the farmers of the middle west must learn to live with the European corn borer and this prediction is now being vindicated. He was

co-author of three books on entomology: "Destructive and Useful Insects," "The Fundamentals of Insect Life," and "Insects: Man's Chief Competitors."

He was especially efficient as an extension entomologist, bringing to the farmers and fruit growers of Illinois, in non-technical language they could fully understand, much valuable advice and help in the constant fight against the insects—an important contribution to the success of Illinois agriculture. By his extensive contacts and very practical advice, he won the gratitude and respect of thousands of people engaged in agricultural work.

He was a Fellow of the American Association for the Advancement of Science and held a number of important positions in the American Association of Economic Entomologists, of which he was Vice-president in 1927 and President in 1932. In 1932 he was Chairman of the Committee on Entomological Exhibits for the Chicago Century of Progress Exposition. In 1942 he served as Chairman of the Board of Trustees of the Crop Protection Institute. He was also a member of the Committee on Crop Protection of the National Research Council.

On January 21, 1911, he married Miss Florence Bell Wraight, who survives him.—C. L. METCALF.

ALBERT H. GREER, a member of our Society since 1924, was born near Brookhaven, Mississippi, January 8, 1891, and died at Calexico, California, July 31, 1943. He was graduated from Mississippi State College in 1917 and was commissioned a first lieutenant in the Army the same year. He served on the Mexican border during the war. For a while he was employed on pink bollworm eradication by the Federal Horticultural Board, then rendered valuable service for many years at El Paso, Texas, in Mexican border inspection for the Bureau of Entomology and Plant Quarantine. He moved to Calexico, California, in 1940. He was keenly interested in the present war and offered his services. Failing to get in the Army because of ill health he became the commanding officer of the Home Guard of Calexico. He was also a member of the American Association of Economic Entomologists. He was a good student, a hard worker, a sincere friend and loyal classmate, and a faithful supporter of his profession. His wife, Maria L. Greer, seven brothers and one sister survive him.—CLAY LYLE.

JOHN CALHOUN HAMLIN, a member of our Society since 1916, was born in Anderson, South Carolina, on September 25, 1896, and died at Starkville, Mississippi, on June 8, 1943, after a brief illness. He graduated from Clemson Agricultural College in 1916 with the degree of Bachelor of Science. Immediately after graduation he was employed by the Federal Bureau of Plant Industry as a citrus canker inspector during the summer. Doctor Hamlin was assistant in zoology and entomology at Ohio State University during 1917, from which institution he obtained the degrees of Master of Science in 1918 and Doctor of Philosophy in 1928. His Doctor's thesis was "An Inquiry into the Stability and Restriction of Feeding Habits of Certain Cactus Insects," which was published in the ANNALS. In 1918–1919 he served as plant quarantine inspector for the Federal Horticultural Board, and in this position became acquainted with the late Dr. W. D. Hunter, to whom Dr. Hamlin gave credit for instilling in him a respect for hard work and a devotion to high ideals. From 1920 to 1923 he was entomologist and biologist for the Australian Commonwealth Prickly-Pear Board which was engaged in the investigation of insects attacking the Cactaceae in the United States and Mexico and their possible introduction into Australia for the biological control of the prickly-pear cacti, *Opuntia* sp., which had been introduced into Australia and had spread over about 60 million acres in Queensland and New South Wales. Dr. Hamlin was officer in charge of these investigations during 1923 and 1924 and through his efforts was successful in importing and establishing in Australia several species of insects which fed upon the prickly-pear cacti.

Following this assignment in 1924 he was appointed Associate Entomologist in the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, to investigate insects affecting dried fruit, with headquarters at Fresno, California. With the expansion of the alfalfa weevil investigations in Utah he was transferred in 1928 to this project and located at Salt Lake City. Upon the completion of these investigations in 1940 to which Dr. Hamlin made notable contributions, he was assigned to a study of the biology and ecology of the Mormon cricket with special reference to the phases which had a direct bearing on large scale control programs for this pest with headquarters at Winnemucca, Nevada. With the inauguration of a long time plant breeding program to develop hybrid

corns suitable for commercial production in the South by the Department of Agriculture in cooperation with the Southern State Experiment Stations, Dr. Hamlin was selected to initiate studies on the entomological phases of this corn breeding problem. These studies were undertaken late in 1942 with headquarters at State College, Mississippi. Those who have worked under his direction were stimulated and inspired by his enthusiasm and solid approach to the problem at hand and because of his sound judgment and wide experience his advice and guidance were often sought by associates working in similar fields. Those who knew him will carry memories of his cordial hospitality, his unfailing kindness, and good sense of humor. His untimely death is felt by his many associates and by it entomology has lost one of its outstanding workers. Dr. Hamlin's publications cover a wide field on both biology and chemical control of insect pests. He was a member of the American Association for the Advancement of Science and the American Association of Economic Entomologists.

He is survived by his wife, Helen Hamlin, and by two daughters of a former marriage.—J. C. DOUGLASS.

WILLIAM ALBERT HOFFMAN, a member of our Society since 1914, a Life Member since 1926, and a Fellow since 1940, was born in Long Branch, New Jersey, April 18, 1894, and died in San Juan, Puerto Rico, on April 4, 1943. He received his B.S. from Cornell University in 1917 and his Sc.D. from Johns Hopkins School of Hygiene and Public Health in 1924. The following year he was a Medical Entomologist of the Haiti Survey of the International Health Division of the Rockefeller Foundation. On the completion of this work in 1926 he was appointed to the staff of the School of Tropical Medicine at San Juan, Puerto Rico, where he was entrusted with the important work of organizing the Department of Parasitology of the then newly founded institution, with which he was so closely identified for the last seventeen years of his life.

At Johns Hopkins he was an assistant of the late Dr. F. M. Root, under whose guidance he completed his Doctor's thesis on the *Culicoides* of North and Central America and the West Indies, and with whom in 1937 he published a comprehensive revision of the North American species of *Culicoides*. He was well acquainted with the mosquitoes and had made several surveys in the Caribbean region. His interests in the whole field of systematic entomology were very broad, and many of the records of insects, particularly of Coleoptera and insects of medical or veterinary importance, in G. N. Wolcott's "Insectae Borinquensis"—a check list of the insects of Puerto Rico—are the result of his work as a collector.

His interests were by no means limited to entomology. His early work in Puerto Rico showed the incidence and distribution of *Wuchereria bancrofti* on the Island and included papers on *Fasciola hepatica*. His later work centered about Manson's schistosomiasis. He published a series of papers written in part with Dr. E. C. Faust and others concerning the distribution of *Schistosoma mansoni* in Puerto Rico, the local species of intermediate snail host of *Schistosoma*, details of biology and epidemiology, improvement of concentration methods in searching for ova in the feces, and refinements in the experimental means of inoculation of animals with schistosome carceriae. With Dr. W. H. Taliaferro he developed a skin test for diagnosing schistosomiasis.

Dr. Hoffman was severely crippled by infantile paralysis at the age of two and could walk only with the aid of special braces. In spite of this difficulty he made frequent field trips and would set a stiff pace for many a younger and more healthy collector. He refused, in fact resented, any offer of aid. By his determination to equal or surpass the endeavors of people more favored physically, his careful observation, and his sound reasoning he became an outstanding scientist and authority on parasitology. Psychologically, he fought an uphill battle all his life, frequently being seized by periods of depression. At such times he often found comfort in playing his beloved violin or viola.

Parasitologists and entomologists will remember him through his contributions to their fields. His more intimate associates will remember him for his ability to inspire enthusiasm in all who worked near him, for his generosity towards those who needed a helping or guiding hand, and for the humble simplicity and almost ascetic austerity of his life.—HARRY D. PRATT.

FRANK E. LUTZ, a Charter Member of our Society, a Fellow since 1917, and its President in 1927, was born at Bloomsburg, Pennsylvania, on September 15, 1879, and died in New York, N. Y., on November 27, 1943, after a lingering illness.

Into the relatively brief span of sixty-four years he crowded activities and accomplishments which would have surfeited a much longer lifetime. Broadly trained in biology and bountifully endowed with great energy and keen vision, he gained international reputation for the excellence of his research on the genetics, physiology and ecology of insects. Always a champion of insects for the large part they play in our everyday life, which is virtually unheralded, he sought to measure the good of the many against the notorious depredations of the few. Always he found the scales heavily weighted in favor of the beneficial kinds and chose to emphasize this fact. Much of his life was devoted toward a graphic presentation of these creatures to the public by means of writings and lectures. The splendid "Hall of Insect Life" in the American Museum, his "Field Book of Insects" and "A Lot of Insects" stand as monuments of his devotion to the field of popular education.

After graduating from Haverford College in 1900 with a degree of Bachelor of Arts he spent several years as student and biological researcher during which he acquired a liking for and became determined to enter the field of entomology. During these formative years he was strongly influenced by the emerging application of statistical methods to biological problems. One of the results was a year spent at University College, London, studying the biometry of Professor Karl Pearson, and other years at the University of Chicago where he continued this type of study under Professor C. B. Davenport. As a Research Investigator for the Carnegie Institution he spent five years on biological investigations at the Station for Experimental Evolution at Cold Spring Harbor, Long Island, New York. He was one of the first biologists to recognize the merits of the fruit fly *Drosophila* as an experimental animal and thus shared in the preparation of the field for epochal discoveries in genetics. Many of Dr. Lutz's papers were concerned with heredity and this subject continued to be of great interest to him throughout his life. One of his most quoted contributions (and one that he belittled for its brevity and the relative ease of preparation of the paper) is concerned with the inheritance of the manner of clasping the hands. The degree of Doctor of Philosophy was granted to Dr. Lutz in 1907 by the University of Chicago. In his thesis, which was entitled "The Variation and Correlations of Certain Taxonomic Characters of *Gryllus*," he demonstrated statistically that many of the so-called "species" of our common black crickets represented little more than geographical or morphological variants.

Soon after receiving the Doctorate, Dr. Lutz was appointed (1909) as an Assistant Curator in the department of Invertebrate Zoology of the American Museum of Natural History in New York, N. Y. For thirty-four years he was identified with the American Museum and for the last twenty-two years until his death he was the Curator of the separate department concerned with Insects and Spiders. Under his personal leadership this department grew rapidly to take its place with the three or four largest entomological repositories in the United States. Although it was one of Dr. Lutz's boasts that he had never described a "new species," he always strongly sponsored systematics and contributed in an unusually vigorous way toward the accumulation of material from which hundreds of species have been named. Many of these species bear his name. More than twenty field trips were taken to all parts of the western hemisphere for field collecting or for special studies. One of the earliest trips took him to Kaieteur Falls in the interior of British Guiana, and ten other ones found him in tropical situations in Mexico, Central America and the West Indies. Within the United States he visited virtually every state and in many of them he spent months making faunal collections or studying biological problems concerned with insects. Although he traveled many thousands of miles in such expeditions, he was always emphatic in the belief that his most interesting discoveries were made in his own back yard at Ramsey, New Jersey.

The role of Dr. Lutz in the field of popular entomology and nature study has been of national import. It was always a personal triumph for him to find that he had been instrumental in directing new devotees into the field of natural history. Sincerity in their interest in insects was the only qualification for audience and advice from him to school boy, business executive, or scientist. Thousands of students and amateurs owe a debt of gratitude to him for the "Field Book of Insects," which was prepared specifically to fill their need for an authoritative primer on insects. Never was he content to allow his numerous

technical research problems to gather dust as learned works. By means of popular articles and lectures he made his discoveries available to a large segment of the population. The first "nature trails" and "trailside museums" are products of his fertile imagination. He was frequently called in as adviser to museums, national and local parks, the various organizations for youth, etc., on problems relating to natural history. Dr. Lutz will long be remembered for his long list of papers which describe his technical research projects of which only a few can be even mentioned here. In 1923 he was awarded the Morrison Prize for a paper which included a study of "The Colors of Flowers and the Vision of Insects with Special Reference to Ultraviolet," in which he showed among other things that there is an invisible color pattern on some flowers which is apparently visible to insects. Other important studies were concerned with geographical distribution, the recording and interpretation of insect sounds, the sensory behavior of the honey bee and stingless bees, and studies on the diurnal rhythm of various insects. In the excellence of his contributions as scientist and educator we find a fitting tribute to his favorite "wonder creatures."—W. J. GERTSCH.

RICHARD ANTHONY VON MUTTKOWSKI, a member of our Society since 1915 and a Fellow since 1940, was born at Milwaukee, Wisconsin, March 4, 1887, and died at Detroit, Michigan, April 15, 1943. He took the A.B. degree at St. Lawrence College in 1904 and at St. Paul Seminary in 1904. The A.B. degree was again awarded him at the University of Wisconsin in 1913. He received the Ph.D. degree from the University of Wisconsin in 1916. He served as an Assistant in the Department of Invertebrate Zoology at the Milwaukee Public Museum from 1906 to 1912. After receiving his Doctorate Dr. Muttkowski was Instructor in Zoology at the University of Missouri in 1916–1917 and at Kansas State College in 1917–1918. In 1919 he was called to the University of Idaho, serving as Assistant Professor of Zoology and Entomology until 1922 and Associate Professor in the same subjects until 1925. Dr. Muttkowski then accepted a Professorship in Biology at the University of Detroit and was head of the Department of Biology from 1925 until his death. During the summers of 1914–1916 he was an investigator for the Wisconsin Geological and Natural History Survey, was an Instructor at the University of Wisconsin in 1916, and served as investigator for the U. S. Bureau of Fisheries during the summers of 1917 to 1925. During World War I he was in the Intelligence Division of the Signal Corps, 1918–1919, and an Instructor with the A. E. F. at the University of Beaune in 1919.

He was a member of the American Association for the Advancement of Science, the American Society of Zoologists, the American Microscopical Society, the Ecological Society of America, the Brooklyn Entomological Society, the Wisconsin Natural History Society, the Michigan Academy of Science and the Wisconsin Academy of Science, of which he was Secretary, 1909–1912, and Editor, 1910–1918.

He will long be remembered for his "Catalogue of the Odonata," 1910.

WILMON NEWELL, a member of our Society since 1907, was born at Hull, Iowa, March 4, 1878, and died at Gainesville, Florida, October 25, 1943. He received his B.S. at Iowa State College in 1897, his M.S. in 1899, and his D.Sc. from the same institution in 1920. He was Assistant Entomologist at the Iowa Agricultural Experiment Station from 1897 to 1899 and held the same position at the Ohio Agricultural Experiment Station from 1899 to 1902. During 1902–1903, he was Associate Entomologist and Apiarist at the Texas Agricultural Experiment Station. From 1903–1904 he was State Entomologist of Georgia. From 1904–1910 he was Entomologist of the State Crop Pest Commission of Louisiana. In 1910 he returned to Texas as Entomologist of the Experiment Station and State Entomologist, the position which he held until 1915 when he went to Florida as Plant Commissioner of the State Plant Board. In 1921 he became Dean of the Agricultural College and Director of the Florida Agricultural Experiment Stations and Agricultural Extension Division. He was a Fellow of the American Association for the Advancement of Science and a member of the American Association of Economic Entomologists (President in 1920). He was a charter member of the Florida Entomological Society and of the Newell Entomological Society, named after him.

Dr. Newell did pioneer research work on the control of the boll weevil in Louisiana and he was very much interested in apiary work in Texas and other

States, but he was best known for his activities in pest control and eradication. On first going to Florida, he was given charge of the campaign for the eradication of citrus canker, a very serious disease which had been introduced, presumably from Japan, a few years earlier. This he carried through to a successful conclusion. In spite of persistent and thorough search, no infested trees have been found since 1927. Upon the discovery of the Mediterranean fruit fly in Florida in 1929, he organized the fight against that pest, which ultimately resulted in its eradication 18 months later.

He married Helen Mabee, of Galesburg, Illinois, in 1907.—J. R. WATSON.

ARTHUR HINTON ROSENFELD, a member of our Society since 1914, was born at Petersburg, Virginia, July, 1886, and died October 6, 1942, at Washington, D. C. He received his B.S. and M.S. degrees at the Virginia Polytechnic Institute. In 1905 he was Assistant to the State Crop Pest Commissioner of Virginia and the same year went to Illinois as a state horticultural inspector. From 1906–1910 he served as Assistant Entomologist of the Louisiana State Crop Pest Commission working on the Argentine ant, especially with relation to sugar-cane insects. When the Tucuman Sugar-cane Experiment Station in Argentina was organized in 1910 he was appointed Entomologist at the institution and later served as Subdirector 1911–1913, and Director, 1913–1916. He also served as head of the Department of Entomology at the University of Tucuman, 1914–1916. From 1916 to 1921 he was Superintendent of Agriculture at the Ingenio Santa Ana, Tucuman, Argentina, the largest sugar Central in the Province of Tucuman. He was Special Technologist for Cane at the Puerto Rico Insular Experiment Station 1923–1926 and Consulting Technologist of the American Sugar Cane League, New Orleans, Louisiana, 1927–1932. From 1932 until his death he was Government Sugar Cane Technologist, Ministry of Agriculture, Cairo, Egypt.

His family was ordered out of Egypt during the summer of 1942 when the threat of invasion seemed imminent and while the airplane trip to the United States was uneventful, his sudden death came only a few weeks later.

He is survived by a wife and a son, Arthur, Jr.

Following the reading of these brief memorials, the members stood in silence in memory of the members who had died during the past year.

The total membership on December 31, 1943, is 934.

The following were recommended by the unanimous vote of the Executive Committee to Honorary Fellowship in the Society: WILLIAM T. DAVIS and ANGELO M. DE COSTA LIMA. These were unanimously elected by ballot of the membership at the Annual Meeting.

The following were elected by the Executive Committee to the Editorial Board of the Annals for the term expiring December 31, 1946: GEORGE M. KNOWLTON, ARTHUR GIBSON and T. H. HUBBELL.

The following were elected by the Executive Committee to the Thomas Say Foundation Committee for the two-year term ending December 31, 1945: A. C. KINSEY and E. O. ESSIG.

The Executive Committee reaffirmed the approval of a loan of $2,000.00 from the Permanent Fund of the Society to the Thomas Say Foundation, to be secured by a five-year non-interest bearing note, and to be used for the publication of a fourth volume of the Foundation's Monographs.

The Executive Committee voted to contribute $100.00 to the Royal Zoological Society of London for the support of the Zoological Record.

The Executive Committee adjourned at 11:00 P. M.

Respectfully submitted,

CLARENCE E. MICKEL, *Secretary.*

On motion the Secretary's Report was accepted and the recommendations of the Executive Committee adopted.

REPORT OF THE TREASURER

CURRENT FUNDS

RECEIPTS

Balance on hand in Bank, December 21, 1942 (See Annals, Vol. 36, p. 153)	$2,424.93
From Annual Dues of Members to December 1, 1943	3,218.62
From CLARENCE H. KENNEDY, Managing Editor of Annals	900.00
From three Life Memberships—H. D. PRATT, WILLIAM ROGOFF and RICHARD H. DAGGY	150.00
From WILLIAM T. DAVIS, Contribution to Union of American Biological Societies	25.00
From sale of one membership list	1.00
Total Receipts	$6,719.55

EXPENDITURES

Postage, including 2,000 three-cent stamped envelopes, and 1,000 one and one-half cent stamps	$ 86.52
Spahr and Glenn Printing Co., Columbus, Ohio; printing December, 1942, and March and June, 1943, Annals	2,222.57
Letterheads for Secretary-Treasurer	7.50
Printing; preliminary announcements, statements, and meeting announcement postcards (including postage and return postage)	61.00
Clerical Services	51.35
Return of overpayment of dues	1.00
Telegrams	14.76
Checks of members returned by bank	8.00
Exchange on checks at bank	17.23
Contribution to Royal Zoological Society of London for Zoological Record	100.55
Contribution to Union of American Biological Societies	50.00
Traveling Expenses, S. A. GRAHAM, representative of the Society, to meeting of joint committee on Coordination of Entomology with the War Effort, Ann Arbor, Michigan, to College Park, Maryland, and return; E. O. ESSIG, representative of Society, to Annual Meeting of Division of Biology and Agriculture, National Research Council, Berkeley, California, to Washington, D. C., and return (in part)	90.91
Transfer Life Membership Payments to Permanent Fund of H. D. PRATT, WILLIAM ROGOFF and RICHARD H. DAGGY	150.00
Total Expenditures	$2,861.39
Balance in Checking Account, December 1, 1943	3,858.16
Total	$6,719.55

LIABILITIES

The Society owes the Publishers for the September and December, 1943, Annals, and for the printing of the programs for the 1943 Annual Meeting. Of the above cash receipts for dues, $1,144.35 is for 1944 and other dues paid in advance.

PERMANENT FUND

RECEIPTS

Balance in Savings Account, December 21, 1942	$3,965.34
Interest on Savings Account, December 21, 1942, to December 1, 1943	39.48
Interest on Liberty Bond 45554-D	1.43
From three Life Memberships	150.00
Total Receipts	$4,156.25

EXPENDITURES

(None)

Balance in Savings Account, December 1, 1943	$4,156.25
One Liberty Bond 45554-D	50.00
Balance in Permanent Fund	$4,206.25

RESOURCES

Liberty Bond 45554-D	$ 50.00
Balance in Savings Account	4,156.25
Balance in Checking Account	3,858.16
Total	$8,064.41

Respectfully submitted,

CLARENCE E. MICKEL, *Treasurer.*

On motion the Treasurer's Report was accepted, subject to the approval of the Auditing Committee.

REPORT OF THE MANAGING EDITOR OF THE ANNALS

The Annals for 1943 will be a volume of about 700 pages, which means that the volume for 1944 may have to be smaller if present size involves an overdraft on 1944.

The Annals has been aided by a gift of $500.00 from a friend and member of the Society, DR. WILLIAM PROCTER, whose name I may now disclose, and to whom for the Society the present Editor wishes to convey thanks. The grant has been a help in time of real need. The gift of a like amount noted in the report for 1942 was from the same source and after closing our books for 1943 we banked a similar amount from DR. PROCTER for 1944. From authors for cuts and for printing, the Annals has received another total contribution of $498.00. For the year 1943 this is a grand total of $998.00 received from friends over and above the amount granted the Annals from the Society's treasury. We are out the income from 76 subscriptions to Axis countries. The total loss here is over $300.00. The Annals is a strictly business venture and lives solely on hard cash income.

We face higher printing costs in the immediate future but the Executive Committee last year turned down the suggestion that the price of the Annals to the members (annual dues) be raised to the level charged at present in other similar biological societies for their biological journals. At present the Annals at $4.00 per year is the cheapest buy on the scientific market.

The Federal authorities have just ruled that the Annals will have to use 45 pound paper during 1944 as against 60 pound paper in the present volume. Illustrations may not appear as well but the same brand and quality of paper will be used.

Last year the new Chairman of our Department, PROFESSOR LAURENCE H. SNYDER, succeeded in convincing the Ohio State University executives that PROFESSOR DONALD J. BORROR should be given, on full University pay, one-third of his teaching time for editorial work on the Annals. This is a gift from Ohio State University to the Society of one-third of Professor Borror's salary. It amounts, in cash, to nearly $1,000.00 per year. Here we express our appreciation and the same for the Society. We hope that contributing authors will bear with the closer and more detailed editing that the Annals is now experiencing.

Much study has been put on format. The Managing Editor is convinced that the present format is one of the things which has attracted the present high grade and beautifully illustrated articles which have come to the Annals in recent years. An author is willing to pay for cuts and willing to put extra hours of hard work on drawing the same, thus producing finer drawings, if he feels that the journal will not discount them on thin, cheap paper or crowd them into a two-column format. The present easy format is a profitable investment in the acquisition of quality articles.

The financial summary follows:

RECEIPTS

Non-member subscriptions	$ 766.71
Back numbers and reprints	221.21
From authors for cuts	425.56
Gift to the Annals	500.00
Contributed for printing	73.00
Bank balance from 1942	45.63
Total	$2,032.11

EXPENDITURES

To engravers	$ 651.67
Office help	250.75
Postage	80.00
Office supplies and upkeep	53.25
Miscellaneous	52.33
Undeposited checks	15.67
Bank balance November 29, 1943	28.44
To Secretary-Treasurer	900.00
Total	$2,032.11

Respectfully submitted,

CLARENCE H. KENNEDY, *Managing Editor.*

On motion the Report of the Managing Editor was accepted, subject to the approval of the Auditing Committee.

REPORT OF THE TREASURER OF THE THOMAS SAY FOUNDATION

RECEIPTS

Balance on hand, January 18, 1943	$372.66
1943 sales of Volume I—1 at $2.70	2.70
1943 sales of Volume II—3 at $4.50	13.50
1943 sales of Volume II—1 at $5.00	5.00
1943 sales of Volume III—3 at $3.60	10.80
1943 sales of Volume III—1 at $4.00	4.00
Interest on Savings from June 30, 1942, to December 31, 1942	2.72
Total Receipts	$411.38

EXPENDITURES

Postage	$ 1.33
Total Expenditures	$ 1.33
Balance in Purdue State Bank, November 26, 1943	$410.05
Due on 1943 sales of 4 copies of Vol. II	$ 15.00

Respectfully submitted,

J. J. DAVIS, *Editor and Treasurer.*

On motion the Report of the Treasurer of the Thomas Say Foundation was accepted, subject to the approval of the Auditing Committee.

REPORT OF THE AUDITING COMMITTEE

We, the undersigned members of the Auditing Committee, beg to report that we have carefully examined the accounts of the Treasurer of the Society, the Managing Editor of the Annals, and the Treasurer of the Thomas Say Foundation for the year 1943, and have found them to be correct and properly balanced. The accounts of the Treasurer were examined by A. G. RUGGLES, those of the Managing Editor of the Annals by R. C. OSBURN, and those of the Treasurer of the Thomas Say Foundation by H. O. DEAY.

Respectfully submitted,

H. O. DEAY,
A. G. RUGGLES,
RAYMOND C. OSBURN, *Chairman.*

On motion the Report of the Auditing Committee was accepted.

REPORT OF THE REPRESENTATIVE TO THE COMMITTEE ON BIOLOGY AND AGRICULTURE OF THE NATIONAL RESEARCH COUNCIL

The meeting of the Division of Biology and Agriculture of the National Research Council convened at the Academy of Natural Sciences, Washington, D. C., on April 10, 1943. The meetings this year were unusually profitable since for the second time a considerable amount of entomological matter was presented. I think you will be interested in knowing that the agenda for the meeting contained nearly a page relating to the entomological features which were presented by your representative last year.

On the program this year was a rather extensive report of the Committee on Crop Protection which was presented by the acting chairman, J. G. LEECH. This report comprised two pages and dealt with the following matters:

1. The organization and work of the Committee.
2. A discussion of the manpower problem as affecting entomologists and plant pathologists.
3. The matter of the effect of military service on personnel.
4. A symposium on dosage experiments with insecticides and fungicides.
5. The problem of plant disease and insect surveys. It was suggested that the word "survey," being in disrepute with administrative officials and legislators, be dropped or a substitute used.
6. The desirability of pooling the efforts of entomologists and plant pathologists for their respective services, placing emphasis on crop loss *estimates* and avoiding the phrases *disease survey* and *insect survey*.
7. The need for investigating the effects on insect populations (and diseases) of the radical changes caused by war needs, in crops grown over wide areas.

DR. C. E. PALM, representative of the American Association of Economic Entomologists, and myself presented some information in connection with entomological matters, and I especially reported on the importance of the study of stored products insects in connection with new packaging materials, particularly with regard to possible loss that may be incurred in connection with the storage of foods in large warehouses over considerable periods of time.

Respectfully submitted,

E. O. ESSIG, *Representative.*

On motion this Report was approved and placed on file.

REPORT OF THE JOINT COMMITTEE ON COORDINATION OF ENTOMOLOGY WITH THE WAR EFFORT

Most of the members of the two entomological organizations are familiar with much of the planning and duties suggested by the work of this Committee from its appointment in the Spring of 1942, through published reports and other means. Nobody, not even the members of the Committee, can evaluate the work as to extent or influence on the production program of the nation. Many of the project leaders named in earlier reports have reported specific progress to the Committee. Others, no less effective, have permitted their published recommendations to bespeak their efforts. In many cases the tasks undertaken by suggestion of the Committee so overlapped the regular duties of leaders and members of projects that there can be and should be no differentiation. Certainly all concerned have shared with all entomologists a desire to make useful all available information to those in immediate need of it and in such form as to be most helpful. That entomologists have made a sincere effort to make the work of their profession useful is not to be questioned.

The methods of transmitting needed information to those at the firing line of production have varied enormously, both as to scope of material and agencies utilized as assistance. In some instances the distribution has necessarily been localized and in other cases widespread, according to the nature of the problem itself. Some leaders have utilized established publication series, while others have discovered new agencies for disseminating entomological information. An

outstanding example of such a new agency is the cooperative effort of several dairy firms for publicizing the work of the Dairy Insect Control.

Several million copies of the very excellent brochure of pests of the dairy industry prepared by this project group have been distributed and are now available for use among dairy farmers, dairy stores and manufacturers of dairy products. In a few cases local circumstances have delayed carrying out the planned efforts so that there has been little to report. On the whole the quantity and quality of the work has been far beyond the early expectations of the Committee, and judging from the ardent endeavor so far, it may be anticipated that all project groups will continue the effort, not to accept an assignment made by others but to reach the goal set by their own determination.

Changes in Organization.—The lamented death of two project leaders and other circumstances make it necessary now to consider some changes in organization. The Committee has not determined the personnel of project groups, and still leaves it to the decision of chairman to make such changes as conditions may now dictate.

DR. WILMON NEWELL was chairman for the South on Citrus Insect Control. His death made a reconsideration necessary, and since control of insects attacking citrus fruits is well covered by existing agencies in the various areas, and since there seems nothing that could be added by project efforts, the Committee has dropped this project.

PROFESSOR W. P. FLINT was project leader for soy bean insects. This project is now placed under the guidance of DR. GEORGE C. DECKER.

It seems advantageous to combine the Hog Insect project with that on beef (horses) and sheep, giving it the name of Domestic Animal project, with DR. W. E. DOVE as chairman.

PROFESSOR FLINT was also chairman of the Corn Insect project and did outstanding work in organization of this effort. The project is now placed under the chairmanship of J. H. BIGGER, fortunately working in the same laboratory as did the late PROFESSOR FLINT. It seems desirable also to establish as a new project Insects Attacking Sweet Corn (especially in the East), under the chairmanship of DR. L. A. CARRUTH.

Sometime back chairmanship of the work on White Potato Insects in the East was transferred to DR. W. A. RAWLINS, but was not previously announced.

Because of the change of the work on domestic animals, the project of which DR. W. B. HERMS is chairman is now limited to Insects Affecting Man.

Since the project on Naval Stores impinges on work on other forest insects, and since there seems to be imminent a great increase in the importance of educational effort on the broader field, the project is broadened to all forest insects, and the Committee requests its member, DR. S. A. GRAHAM, to cooperate with DR. F. C. CRAIGHEAD, in a study of the changes incident to the new plan.

All new designations of project leadership remain subject to acceptance of assignments.

Quotas for 1944 production should be available shortly and all project chairmen should inform themselves of any changes in quotas as indicative of the urgency of effort in their respective fields.

Insect Pest Survey.—Changes in conditions incident to the war make it especially important that at all times entomologists be aware of shifts in insect populations and regarding incipient outbreaks. We cannot too vigorously emphasize the handicaps imposed at a time like this by the restriction in scope and size of the Insect Pest Survey, resulting from severe reduction in financial support of this cooperative federal and state activity. Entomologists recognize the need for economy, but believe that they are in better position to appreciate the seriousness of such a change in the survey than are persons unfamiliar with the usefulness of this undertaking. Persistent and concerted efforts should then be made to bring about a restoration of the Survey. The Committee proposes no avenue of approach, but leaves that problem to the Officers of the two organizations. It seems incumbent on all entomologists to urge that funds be restored, not only for restoration of the Survey to its former scope but for an ultimate increase in its scope.

New and Proposed Changes in Insecticide Regulations.—The control of insect pests involving the use of insecticides may be seriously impeded by proposed conflicting laws and regulations dealing with coloring of insecticides with specific

colors. Entomologists agree that distinctive markings may well be required, but believe that every effort should be made to prevent imposition of conflicting and impracticable regulations. Whatever regulations may ultimately be enacted, it seems especially important that they be uniform as between the states, and that they do not interfere with the distribution of insecticides in the present emergency.

Respectfully submitted,

E. N. CORY,
S. A. GRAHAM,
J. S. HOUSER,
L. M. PEAIRS,
E. F. PHILLIPS, *Chairman.*

On motion this Report was approved and placed on file.

REPORT OF THE JOINT COMMITTEE ON MILITARY ENTOMOLOGY

Your committee on military entomology has continued to function throughout the year. A considerable number of War-Work Training, Experience and Availability Forms have been executed by entomologists throughout the country and added to our files. These files carry the most complete information existing, in readily available form, regarding the training and experience of entomologists in this country. They have been accessible to the military authorities and have served in many instances as a basis for selecting men for entomological assignments in the military services.

The committee has maintained close contacts with the appropriate personnel officers of the Army and Navy, and the needs of those services for entomological personnel. It has aided many entomologists in civilian life to become commissioned for entomological work, or upon induction into the service to be assigned where they would have opportunity to perform work in entomological or related fields where their training and experience could be used to advantage.

Special attention has been given to the matter of bringing to attention of appropriate officers men in the ranks who by training and experience would make good commissioned officers for entomological work or would serve effectively on special entomological assignments. At present more than 40 entomologists who were serving in the ranks have been commissioned in the Sanitary Corps. The number of entomologists commissioned in the Sanitary Corps of the Army now exceeds 200 and about 100 have been commissioned in the Hospital Volunteer Corps Service of the Navy. A large number of men with entomological training or experience have been attached to Malaria Survey and Control Units of the Army and Navy for overseas antimalaria work. The number of these units now activated exceeds 200.

Your committee has been concerned largely with aiding the military in the procurement of suitably trained men for entomological assignments, and to place entomologists in the military services where their training and experience can be utilized most effectively. In its actions in this regard, however, the committee has not lost sight of the entomological manpower situation as a whole and has endeavored to aid as much as possible in preventing the disruption of teaching, research, and especially extension and control activities in entomology. Thought has been given also to post-war problems in which the services of men now in medical entomological work in the Service may be utilized in that general field at the close of the war.

Respectfully submitted,

ROBERT MATHESON,
E. N. CORY,
F. C. BISHOPP, *Chairman.*

On motion this Report was approved and placed on file.

REPORT OF THE COMMITTEE ON RESOLUTIONS

1. WHEREAS, We believe there has never been a time when it was so important for entomologists to hold national meetings as during the present critical war, as a means of perpetuating the cooperation of all of our members and as an opportunity for the exchange of important ideas,

Therefore, Be It Resolved, that we record our gratitude to the Committee for Local Arrangements—T. H. PARKS, Chairman, NEALE F. HOWARD and DWIGHT M. DELONG—and to the Officers of our Society for planning this meeting and for the splendid facilities secured for our meetings, including the use of tables as well as chairs for the members; and to the managers of the Deshler-Wallick Hotel for the use of their comfortable and attractive rooms and other facilities.

2. WHEREAS, the addresses given by invitation were splendid reports which demonstrated a commendable spirit of cooperation between our military men and the entomologists, and revealed a genuine appreciation of the importance of entomology in the present war effort,

Therefore, Be It Resolved, that this Society express its appreciation and thanks to MAJOR R. H. OZBURN of the Royal Canadian Army Medical Corps; and to the following representatives of the Sanitary Corps of the Army of the United States: COL. W. A. HARDENBURGH, Sn. C., MAJ. O. R. MCCOY, M. C., MAJ. ALDEN E. STILSON, Sn. C., MAJ. STANLEY J. CARPENTER, Sn. C., CAPT. D. G. HALL, Sn. C., LT. W. D. REED, C. E.; to LT. R. H. DAGGY, H-V (S) of the United States Navy; and to Senior Surgeon S. B. FREEBORN and Senior Entomologist G. H. BRADLEY of the United States Public Health Service, for their contributions to our program.

3. WHEREAS, during the past year the Entomological Society has suffered serious and lamentable losses due to the death of the following members: M. W. BLACKMAN, E. D. BALL, R. W. DOANE, W. P. FLINT, A. H. GREER, JOHN C. HAMLIN, W. A. HOFFMAN, FRANK E. LUTZ, R. A. MUTTKOWSKI, WILMON NEWELL, and ARTHUR ROSENFELD,

Therefore, Be It Resolved, that we record our appreciation of the splendid services these entomologists performed during their lives and that our Secretary send to the surviving relatives of each deceased member a note of the sympathy expressed by all of us.

4. WHEREAS, the officials of Ohio State University have generously instructed the Department of Zoology and Entomology of that institution to allow PROFESSOR D. J. BORROR to devote one-third of his time to the editing of the Annals of our Society,

Therefore, Be It Resolved, that we express our appreciation of this to PROFESSOR LAURENCE H. SNYDER, Chairman of the Department of Zoology and Entomology, and to DR. ALPHEUS SMITH, Dean of the Graduate School of Ohio State University.

5. WHEREAS, it has been made known to the members of the Society that DR. WILLIAM PROCTER has made a gift to the Annals of the Entomological Society of America, of five hundred dollars for each of the years 1942, 1943 and 1944,

Therefore, Be It Resolved, that the Society extend its sincere thanks to DR. PROCTER and that the Secretary be instructed to write to DR. PROCTER expressing our appreciation.

6. WHEREAS, the greatest hazard to men on the foreign battle fronts is insect-borne diseases, which are already reported to have caused far more morbidity and fatalities among our military forces than our human enemies have,

Therefore, Be It Resolved, that the Entomological Society of America believes and recommends that our military authorities and other administrators should schedule Medical Entomology and Insect Control courses as a part of the training of all servicemen in the various colleges and universities where these courses are available.

7. WHEREAS, we believe that the most important function of our annual meetings is to learn about the new discoveries our various members have made and the research that they are doing so that we may all cooperate most efficiently,

Therefore, Be It Resolved, that at future meetings the members of the Society be invited and permitted to present papers revealing their recent discoveries, the results of their research and other observations at paper-reading sessions, instead of restricting the program to persons invited by the Program Committee, to give addresses, many of which cover only well-known and long-established facts about our science.

Respectfully submitted,

DAVID G. HALL,
JOSEF N. KNULL,
C. L. METCALF, *Chairman*.

On motion the Report of the Resolutions Committee was adopted.

REPORT OF THE NOMINATING COMMITTEE

Your Committee places in nomination the following Fellows of the Entomological Society of America to fill the designated vacancies for the year 1944:

President—CLARENCE E. MICKEL.
First Vice-President—ROGER C. SMITH.
Second Vice-President—W. J. BROWN.
Secretary-Treasurer—HERBERT H. ROSS.
Two Members of the Executive Committee to Serve until 1946—STUART W. FROST and P. A. READIO.
Councilors to the American Association for the Advancement of Science—W. D. FUNKHOUSER and C. P. ALEXANDER.

Respectfully submitted,

WILLIAM A. RILEY,
CHARLES T. BRUES,
H. B. HUNGERFORD, *Chairman.*

On motion the Report of the Nominating Committee was accepted and the Secretary instructed to cast a ballot for the election of the persons nominated. This being done, they were duly elected.

Following the transaction of the above business, the meeting adjourned.

Respectfully submitted,

CLARENCE E. MICKEL, *Secretary.*

NOTICE TO MEMBERS AND CONTRIBUTORS

The Annals of the Entomological Society of America, published by the Society quarterly, includes the Proceedings of the Annual Meetings and such papers as may be selected by the Editorial Board.

Papers may be submitted to any member of the Editorial Board and should be as nearly as possible in the form desired as final, typewritten, and illustrations finished complete ready for reproduction. Plates must not exceed $4\frac{1}{4}$x$6\frac{3}{4}$ inches unless intended to fold. Cuts for illustrations are charged at cost to the author. In general, papers to be accepted must be original, complete and previously unpublished. Authors will be allowed fifty reprints gratis and additional copies at cost to the Society.

The Managing Editor is provided with the most recent address of all paid-up members on record in the Secretary's office for mailing the numbers of the Annals and members failing to receive their numbers should present their complaint to the Managing Editor within four months from the date of the mailing of the issue. After that time the numbers will be furnished only at the regular published rate.

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CONTENTS OF THIS NUMBER

PAGE

HUFFAKER, CARL B.—The Temperature Relations of the Immature Stages of the Malarial Mosquito, *Anopheles quadrimaculatus* Say, with a Comparison of the Developmental Power of Constant and Variable Temperatures in Insect Metabolism 1

CARTWRIGHT, O. L.—New Scarabaeidae from United States (Coleoptera) 28

BOESEL, M. W., AND SNYDER, E. G.—Observations on the Early Stages and Life History of the Grass Punky, *Atrichopogon levis* (Coquillett) (Diptera: Heleidae) 37

ISELY, F. B.—Correlation Between Mandibular Morphology and Food Specificity in Grasshoppers 47

DELONG, DWIGHT M.—A New Species of *Plummerella* (Homoptera, Cicadellidae) from Mexico 68

DEBACH, PAUL—Environmental Contamination by an Insect Parasite and the Effect on Host Selection 70

KNULL, J. N.—Notes on *Agrilus* with Descriptions of Two New Species (Buprestidae: Coleoptera) 75

ROTH, LOUIS M., AND YOUNG, FRANK N.—*Culex* (*melanoconion*) *atratus* Theobald in Florida; A New Continental North American Record, with Notes on the Other Melanoconions of the South-Eastern United States 84

WEBER, NEAL A.—The Neotropical Coccid-tending Ants of the Genus *Acropyga* Roger 89

KNULL, DOROTHY J.—Nomenclatorial Notes on Cicadellidae 123

Proceedings of the Thirty-eighth Annual Meeting of the Entomological Society of America 124

Book Notices 69, 83, 88, 123

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